spaceflight

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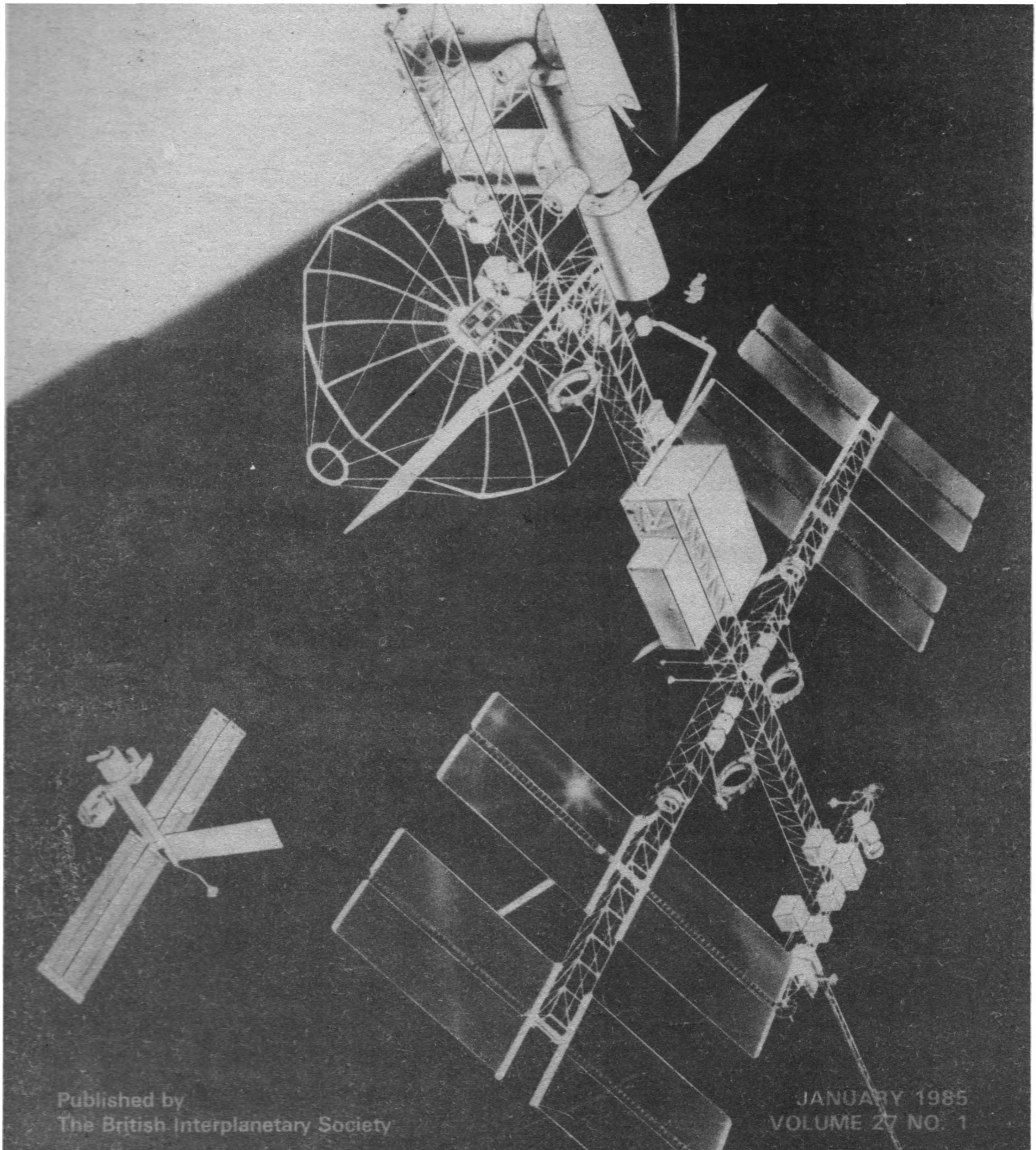

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spaceflight

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THE CASE FOR A NATIONAL SPACE AGENCY

On 21 February 1960 the Society placed before HM Government recommendations on the course of a British/European space programme. Among its many far-reaching proposals was one for setting up a National Space Agency, as it was clear even then that the implementation of a plan involving so many diverse interests, some of them conflicting, required a high degree of coordination and monitoring not only to achieve what was best in our national interests but also to ensure that this would be maintained. It was perceived that a policy of uncoordinated endeavours and the fragmentation of activities would inevitably lead to a loss of direction, urgency and purpose, and fractionise our national resources.

This single central agency was to represent all government interests in space and to have the following objectives:

1. To be seen as the UK focus for space activities.
2. To establish basic objectives and to hold the balance between differing activities and interests.
3. To provide direction, coordination and cohesion.
4. To oversee space activities generally and to act as our national authority in international space ventures.

Throughout the last two decades, however, there appears to have been no conscious discussion of the pros and cons of such a step for, arguably, there might be reasons against it as well as for it. The need, clearly, is for an open discussion to enable all the relevant points to be aired and a balance struck. The fact that objections existed in responsible quarters cannot be denied. Problems of policy, administration and economics are clear enough. Nonetheless, official inaction at this stage will be tantamount to real death of UK space hopes, so the time is now opportune to raise the matter again and pose it as one for serious deliberation by those holding the power of decision in our land.

By way of background we reiterate the following real areas of concern.

Firstly, we underline the point that now is the best opportunity the UK has had for more than a decade to get right into the field of space technology once more. If it is missed, another chance may not emerge for decades.

Secondly, no space programme should be isolated from the rest of the nation. Its purpose should be to raise the whole level of our scientific and industrial capability. The money is spent, least of all, 'up there.' It goes into knowledge, facilities and expertise 'down here.'

Thirdly, it follows that, e.g. the role of the smaller company needs to be very carefully evaluated. A plethora of companies

Continued overpage

COVER

NASA'S 'power tower' Space Station reference concept. About 150 m in total length, five pressurised modules will provide living space for six to eight occupants. A co-orbiting platform serviced by the station is seen in the background; this would carry experiments and instruments undisturbed by manned activity. *NASA*

involved in a project raises all sorts of problems of coordination, management and synchronisation - the frustration level can be high. On the other hand, recent history tells us all too plainly that many smaller companies may possess an expertise that can be extremely valuable. Many appropriate supporting roles of this sort spring to mind, e.g. those in the field of data management and information technology generally.

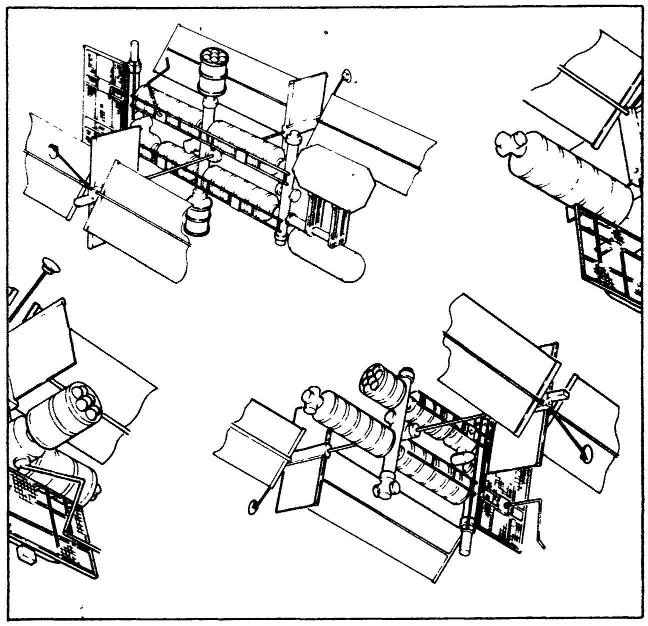
Fourthly, matters like this involve detailed and expert appraisal of projects over a wide area. How this should be done is a problem. ESA, for example, adopts the aim of returning to each participating country an equivalent allocation of contracts for its home industry. This is undoubtedly fair and convenient, but still leaves exposed the question of whether it is best able to provide the support needed. The problem revolves around whether one adopts a global view, i.e. the best interest of the *project* or, basically, tries to accommodate the problems of sociology and economics in individual countries.

To turn now the main task. We have to face the fact that the reasons why President Eisenhower formed NASA are as cogent here as in America two decades ago. First, there was the matter of reducing competition and misunderstanding between various arms of government and the services and, second, the need to set up a *competent* agency. Both reasons impelled the President to pull in a nucleus from outside, in order to overcome the bureaucracy. We have two even more essential reasons. Not only do we need to revitalise whole sections of British industry by spreading new concepts, directives and techniques among companies and organisations large and small, but we also have a need for a visionary approach to build up our people's morale. We have the technological personnel today, but where is "Next Generation Britain?" Major developments in the history of mankind are now taking place and yet few of our populace appear to be aware of it. The media rate it just a few lines, while blowing up trivia out of all proportion. Do they take this attitude simply because they discern a lack of space interest in Government quarters? A national space agency, by its very nature, provides the stamp of authority the subject deserves. The Space Station is a project that promises both opportunity and incentive. If we grasp it we will be much better equipped to bridge the industrial chasms *opening up today* before the aerospace and electronics industries.

A National Space Agency will make it easier for ESA, NASA and all other agencies to negotiate with us, besides creating a competent position to proffer advice to the Government on a rapidly expanding and developing area frought with opportunity and promise but which requires the most continuing and comprehensive study.

What would be the major practical steps to be taken the minute a National Space Agency appeared? They can be identified at once, i.e.

1. Establish its own core programme.
2. Settle its priorities. We are looking for a continuing UK space policy, so it should set up a long-range programme, say, over a 15 year span, rather than the five year periods currently preferred.
3. Establish its users and provide user-participation.
4. Establish its relationships with industry, i.e. both in contractual development and exploitation and commercial operation.
5. Provide a coherent voice on space matters, seeking a comprehensive rather than a fractional approach and establish its lines of presentation to, and in association with, the public and groups of all sorts.
6. Consider, very carefully, its role in education and in public policy, and be sure to provide an adequate contact point both with the media and the public generally.



A good deal of this is open to further comment and argument and, provided that this is well-founded and informed, rather than prejudicial and serving self-interest, this could be most useful. For example, the provision of a competent Director and staff, the access points for technical and scientific input and preventatives against an inbuilt ostrich-like approach are all vital to the success of the idea. In such an enormous field and one where past heights of personal glory may have little relevance, a problem could arise on the choice of Director alone. Traditionally, such plums go to the older dignatory or to a personality honoured in other fields. For a newly-created space agency this could prove a disaster.

Again, it may be argued that questions of policy will not be solved simply by setting up a National Space Agency. This is undoubtedly true, and desirably so, but, at least, our country would have a better chance of getting off on the right foot with such a body to deliberate and advise, and answerable both to Parliament and to the public itself.

An even more cogent problem concerns funding. There are the matters of not only how much a National Space Agency will cost (and will it earn its keep?) but will it demand more from the national cake than we can afford, and at a time when taxation is at throat level and with a Government expenditure already grabbing probably more than 60% of our entire nation's output.

From the point of view of the scientist, who, in many cases may represent the initial 'user' of space facilities, the needs are for an easy route of access into space, with funding and management clearly identifiable and also the recognition that much space work actually has to be done here 'on Earth' - with robotics as a current prime example.

These are all arguments for deliberation. Nothing can be gained by over-simplifying recommendations but these are all points that can be deliberated over and overcome. The response 'We will do it - but not now!' is no longer satisfactory. We need an unequivocal 'We will *do* it.'

The matter is now ready to be fully aired and a decision taken.

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1. The case for a United Kingdom Space Programme, *Spaceflight*, 8(10), October 1966, pp.347-354.

SPACECAB II: A SMALL SHUTTLE

By David M. Ashford*

The full exploitation of space depends on the reduction of launch costs. The author describes a proposal for such a concept developed from earlier *Spaceflight* and *JBIS* contributions.

Introduction

An earlier article on Space Tourism [1] described a new type of launcher, called Spacebus, intended to meet the requirements of regular passenger transportation to and from space hotels. Spacebus is of advanced design since it requires standards of safety, comfort, reliability and costs approaching those of today's airliners. Its development would clearly benefit other space enterprises. Mention was made of a step-by-step development strategy for Spacebus involving, firstly, a rocket-powered research aeroplane and, secondly, a partially-reusable small shuttle called Spacecab [2].

Since then, Spacecab has been reconfigured as a fully reusable concept, scaled down from Spacebus. The new concept, called Spacecab II, is much more attractive and probably more relevant to short-term European space transportation requirements.

Spacecab II Description

Spacecab II is a two-stage vehicle of roughly the same size as Concorde and not unlike some of the 1960's Eurospace Aerospace Transporters in appearance. However, it has been designed for minimum development cost and makes full use of developments since the earlier studies.

The Booster stage is a medium sized supersonic aeroplane. Four Olympus turbojets are used for take-off, acceleration to Mach 2, flyback and landing. Two complete Ariane second stages are buried in the rear fuselage to accelerate from Mach 2 to the separation speed of Mach 4.

BOOSTER			
	Span, m	28.3	
	Length, m	64.8	
	Engines		
		4 x Olympus to M = 2	Concorde
		2 x Viking IV to M = 4	Ariane 2nd Stage
	Separation Speed	M = 4	
	Weights, Tonnes:		
	Empty	74.0	
	Payload	41.0	
	Fuel	66.0	
	All-up	181.0	Concorde
ORBITER	Span,m	16.3	
	Length,m	16.8	
	Engines	6 x HM7	Ariane 3rd Stage
	Weights, Tonnes		
	Empty	6.1	
	Payload (and crew)	1.0	
	Fuel	33.9	
	All-up	41.0	

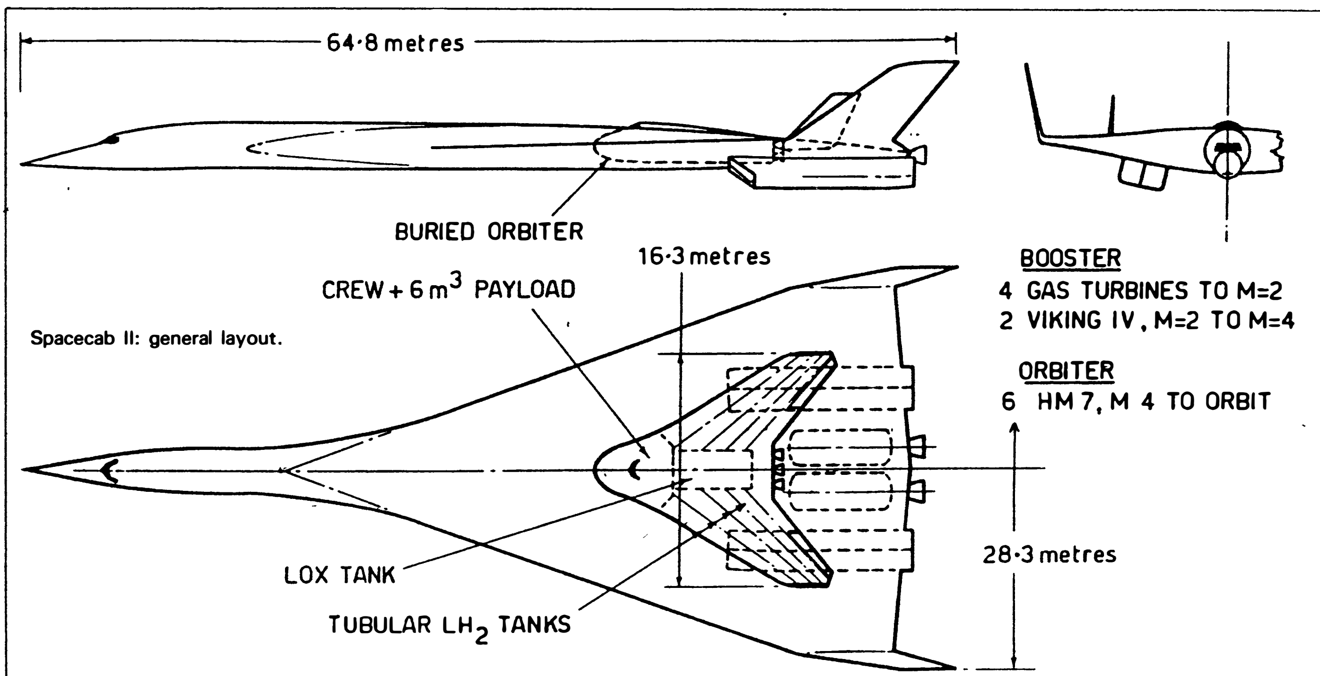
The Orbiter stage has a blunt swept configuration dominated by the liquid hydrogen tanks, which make up about 65% of the stage volume. The payload bay is behind the two man cockpit and has a useful volume of 6 m^3, which is similar to that of a medium-sized van. Six Ariane third stage engines (HM7) are fitted. The Orbiter is partially buried in the Booster to protect it from air loads during the boost phase and to reduce the supersonic wave drag penalty. As a result, the Booster/Orbiter combination is as clean as Concorde.

Leading data, derived from first order sizing calculations, are given in the table.

Spacecab II Uses

As a fully reusable vehicle operating like an aeroplane from existing airfields, Spacecab II would be suitable for the passenger transportation segment of an embryonic space tourism industry. However, its small size (six passengers) would limit its use to the pioneering phase. It would also serve as a technology development vehicle for the larger and more efficient Spacebus. However, its most important early use would be as a general purpose launcher suitable for small (about 750 kg) manned payloads to low orbit.

Existing or planned launchers are not well suited for this



Spacecab II: general layout.

* British Aerospace Dynamics Bristol. Note: The views expressed are those of the author and not necessarily those of British Aerospace. (Spacecab II was described in a paper on Space Tourism presented at the BIS Space Transportation and Space Station Symposium, 11 April 1984).

purpose. NASA's Shuttle is designed for large payloads to low orbit and Ariane is optimised for large unmanned payloads to geostationary orbit. Ariane 5 as planned could launch a small manned payload, Hermes, to low orbit, but at very high cost because of the throw-away booster elements. The fully reusable Spacecab II could therefore be the most efficient vehicle for smaller manned payloads to low Earth orbit. As such it would be ideally suited for carrying:

- Rescue crew
- Mechanics and spares for satellite repair.
- Construction crews for large space structures.
- Small experiments.
- Mechanics for in-orbit assembly of payloads for onward transportation to geostationary orbit.
- Military payloads.
- Space station re-supply payloads.

The last mission listed is probably the most relevant to present European plans. The vehicle scenario emerging for the 1990's is of a large US space station, NASA's Shuttle and derivatives, an ESA successor to Ariane 4 and a small European space station called Columbus. In this context a small reusable shuttle like Spacecab II would be invaluable for complementing the much larger NASA Shuttle for supporting the large US space station and Columbus. It would be ideal for small support payloads not requiring the large capacity of the NASA Shuttle, such as crew replacement, spares, consumables, VIPs, repair crew, medical emergencies, replacement modules and returned samples or processed products. For small payloads of this nature, Spacecab II would be much cheaper to operate than NASA's Shuttle, which would still be used for launching the space stations and for re-supply missions requiring a large payload. Spacecab II would therefore be a most useful complement to existing or planned space vehicles and could be an ideal European contribution to the NASA/ESA programme for the 1990's.

Development Costs

At first sight it might seem that Spacecab II would cost several £Billion to develop and, indeed, further study might show this to be the case. If so, then Spacecab II would have to take its chance as a possible major European project of similar cost and management complexity to Ariane or Spacelab. However, the Spacecab II concept has several features that *raise the possibility* of a demonstrator prototype that could be developed as an aeroplane rather than as a manned spacecraft, leading to a factor of 10 reduction in costs up to the first orbital flight. This would put it within the financial reach of the UK alone. These features are as follows:

Complete Reusability: Spacecab II is completely reusable and has weight margins adequate for a robust structure with long life and low maintenance cost. In terms of cost per flight the advantages of reusability speak for themselves. All spacecraft so far have involved expendable launcher components - the fundamental reason for the exotically high cost of space transportation to date.

In terms of development cost, reusability allows an aeroplane-like test flight programme in which the flight envelope and systems operation are progressively explored, starting with subsonic flights and working through supersonic, hypersonic and sub-orbital flights until orbit is achieved. Spacecab II, although a manned space vehicle, can therefore be man-rated as an aeroplane. By contrast, previous manned spacecraft have been launched by vehicles with expendable stages. The resulting very high cost per flight has drastically reduced the affordable number of test flights. The spacecraft were therefore launched to the near extreme of the flight envelope (orbit) after very few flights, leading to very expensive ground testing, reliability demonstration, redundancy and quality control to ensure astronaut safety.

Existing Engines: Both the Booster and Orbiter use derivatives of existing engines, namely the Olympus turbojet and the Viking IV and HM7 rocket motors from Ariane.

Buried Orbiter: The Orbiter is partially buried in the Booster. This permits an ascent trajectory in which the air loads on the Orbiter are not a design factor (which they are for existing launchers). This enables the shape and structure to be optimised for re-entry, abort and landing. The result is a swept blunt configuration with a very low re-entry wing loading, thereby minimising re-entry heating. Moreover, the structure can be designed for a low equivalent airspeed, allowing a lightweight design to be adopted.

Existing Technology: Spacecab II involves *no* technology, hardware concepts or operating techniques that have not already flown on aircraft or spacecraft, with the possible exception of the Orbiter structure in which multi-cell pressure-stabilised propellant tanks also form the wing structure. This is a simple enough concept that has been proposed for numerous launcher projects but not actually built.

Taking the above features into account there is *no obvious reason* why the development cost of the Spacecab II Orbiter and Booster to first orbital flight should each be much more than that of a demonstrator prototype advanced aeroplane. The going rate for such prototypes is in the region of £50 to £200 million. Taking the upper end of this range, the Spacecab II cost to first orbital flight *could* be as low as £500 million (twice £200 million with extra because the cost of engine spares will be high until the engine life evolves to tens of hours rather than tens of minutes).

Conclusions

A reusable small launcher, Spacecab II, has been described which would be a very useful complement to planned space transportation vehicles. Its main purpose would be logistic support of a large NASA space station and a small ESA one. It would also be ideally suited for rescue, satellite repair, carrying the construction crew for large structures, small experiments, in-orbit assembly and military purposes. It would also be suitable for passengers and could therefore be the next step towards a space tourism industry, perhaps using a derivative of Columbus as a space hotel.

By adopting certain design features and a particular development strategy it seems *possible* that Spacecab II could be developed as an aeroplane, rather than as a manned spacecraft, leading to development costs that could be afforded by the UK alone, as a contribution to the ESA/NASA programme for the 1990's. This possibility seems sufficiently attractive to justify further study.

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2. D.M. Ashford, "Project Spacecab: A Minimum Cost Orbital Taxi," *JBIS,* **34**, 3-9 (1981).

Nothing is New

Sir, Your nine points (*Spaceflight* editorial, November 1984) have a familiar ring. They remind me of Fray Hernando de Talavera's objections to the proposed voyage of Columbus, which ran as follows:-

1. A voyage to Asia would require three years.
2. The Western Ocean is infinite and perhaps unnavigable.
3. If he reached the Antipodes he could not get back.
4. There are no Antipodes because the greater part of the globe is covered with water, and because Saint Augustine says so.
5. Of the five climatic zones, only three are habitable.
6. So many years after the creation it is unlikely that anyone could find hitherto unknown lands of any value.

On the basis of these recommendations, in 1491, the entire project was rejected. Just as he was about to give up he found one more friend, who caused the decision to be reversed and so allowed Columbus to set out on his epoch-making trip the next year.

It is interesting to reflect that, although it took Columbus several years to get his enterprise accepted, he was able to complete the project relatively quickly once he had the go-ahead. In fact, the equipment to perform his new mission was already in existence: the problem was simply to develop an understanding of how far it could be pushed and what wonders were left to explore.

To adopt a more latter-day economic argument, it was only in 1962 that President Kennedy proposed forming the Comsat corporation. At that time the feasibility of geostationary satellites had not been demonstrated, let alone their value perceived. It took a gamble on a 15 year economic horizon to allow the programme to go forward. The UK stepped in during the early 1970's as a 'fast second' and benefitted accordingly, but this may not always be possible. Once in a while, one must gamble on a '15 year horizon' instead of the usual '5 year horizon' common to today's industry.

According to a TRW study the US Government nowadays collects more taxes *each year* from users, builders and sellers of communications satellites and services than the total NASA R&D Investment in Comsats during the 1960's!

CAPT. R.F. FREITAG
Virginia, USA

Superior Intelligence, or Inferior Argument

Sir, I recently had an opportunity to discuss with Dr. Logsdon, personally, his appearance in the BBC *Horizon* programme which was the subject of the editorial in the November 1984 issue.

His comments can be summarized as follows:

1. He was given no idea of the framework nor where he was going to be in the programme.
2. He was simply asked a series of questions.
3. In general, he remains absolutely convinced that he expressed himself very positively as "one of the stronger allies" of the space movement. *In no way had he expected to be regarded as an* "anti."
4. His contribution had been to set up an accusation and then knock it down (i.e. a Devil's Advocate), though remaining adamant that the idea of selling the space station concept solely on the basis of short-term commercial returns is not feasible.
5. He believed that the BBC had been seeking someone specifically to "counter" the offical NASA position.

It seems clear from this that those of his remarks deemed most appropriate were clipped out of the interview, used out of context and passed off as an authoritative opposition.

This, in my view, is one of the most easy and most unsavoury methods of deception.

L.J. CARTER
Executive Secretary

Ignorance Still Rules

Sir, I agree totally with your hard-hitting editorial in the November 1984 *Spaceflight*. It hits all the old anti-space arguments and knocks them out cold, though there will always be those people who denounce such things as space research as a waste of money so long as poverty, etc exist on Earth.

I recall an "Any Questions" (BBC Radio 4) programme during the height of the Apollo Moon flights, in which a well-known trade union leader answered a question on space research expenditure. His answer was that the only benefit was the invention of non-stick frying pans!

CHRISTOPHER ALLAN
Stoke-on-Trent

SNIPPETS

Sir, Re the *Spaceflight* editorial (November 1984 issue) on the James Burke programme, if robots are so damned good, why don't scientists on the ground replace themselves with robots in their laboratories?

I agree that robots should be used for the automated, repetitive functions and thus leave the rest of us free to use our intellect.

P.R. FRESHWATER
Oxon

Sir, It has been three long years since I last received an issue of *Spaceflight*. When I was forced to give up membership (those dreaded finances) it took a while to get used to the idea of not receiving that monthly welcome addition to my library.

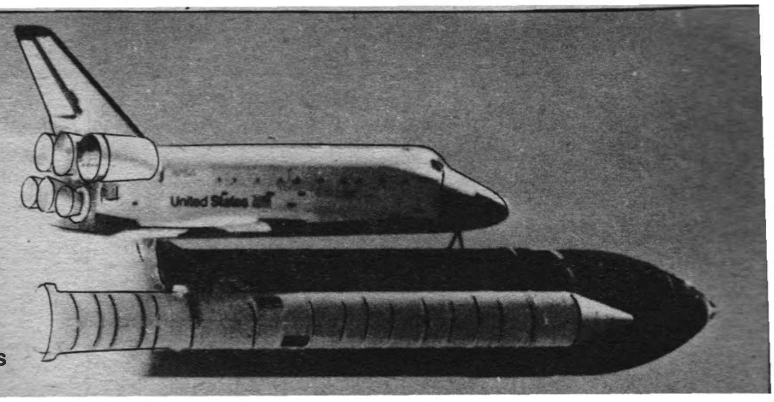
Well, the prodigal returneth. I have always held the BIS in the highest esteem and on those occasions when one hears mention of it on TV or reads of reference to it in the press I think, "I used to be a member of the BIS." I wish to be able to say, "I am a member of the BIS" again. To achieve that end, I respectfully request details of membership dues and conditions again.

RICHARD BARANIAK
Australia

The Editor is always interested in receiving items of correspondence, notes, comments, or reviews for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine. The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.

SPACE REPORT

A monthly review of space news and events



ASTRONOMY

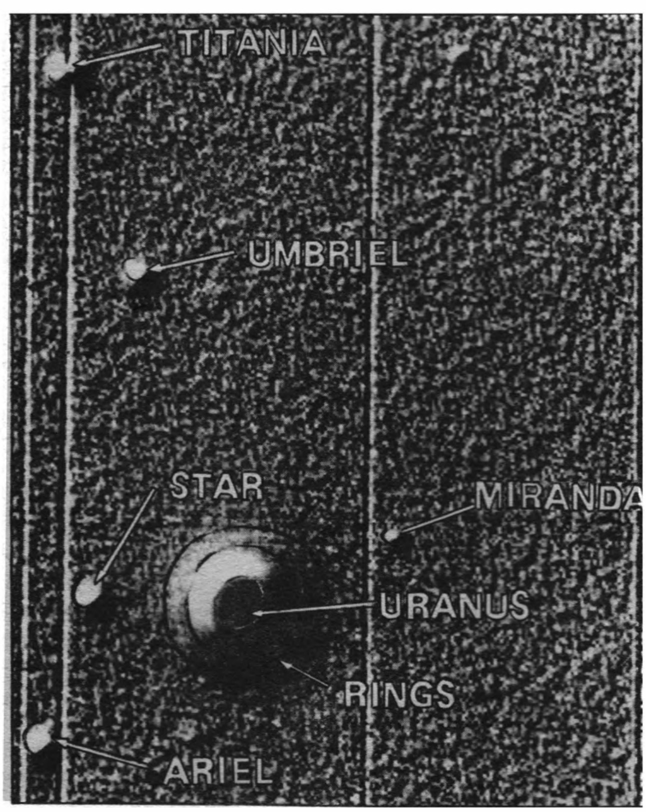
RINGS OF URANUS

Astronomers have clearly photographed the rings of Uranus for the first time, showing them to be made of particles that are possibly the darkest found in the Solar System. Drs. Richard Terrile of NASA's Jet Propulsion Laboratory and Dr. Bradford Smith of the University of Arizona used a charged-coupled device camera system at the Carnegie Institution's Las Campanas Observatory in Chile to record the images last April.

Photographing the rings is difficult because they are darker than charcoal and close to the much brighter Uranus. Computer processing was performed to make the rings visible.

The rings can be seen as a circle of material concentric around the nearly pole-on view of Uranus. (Uranus orbits with one pole facing the Sun; the rings girdle the planet's equatorial region, giving the Uranian system its bullseye-like appearance). The five known moons can also be seen, along with several background stars.

The rings were discovered in 1977 when they blocked out the light of a distant star just before and after Uranus passed in front. The known nine rings are very narrow,



with the widest of them, called the epsilon ring, having an average width of about 50 km.

Analysis of the new photographs shows the rings reflect back only about 2% of the sunlight falling on them, making them possibly the darkest material found in the Solar System. This raises the question as to their composition. Two possibilities have been suggested. Evidence from meteorites and observations of asteroids suggests that dark organic material is prevalent in the outer Solar System; another possibility is that they are made of frozen methane, another common material in these regions. Methane ice, which is normally bright, can be darkened by radiation, either by high-energy particles from the Sun or from trapped radiation around Uranus (similar to the van Allen radiation belts around the Earth).

Studies of the rings are particularly important because they will contribute to preparations for the encounter of Voyager 2 in January 1986.

SIRTF INVESTIGATORS

NASA has selected the scientists who will form the Science Working Group for the Space Infrared Telescope Facility, the next generation of Earth-orbiting observatories for infrared astronomy. The scientists were chosen following a review of proposals solicited from the scientific community in 1983. Investigators were sought in several different categories: focal plane instrument investigators, facility scientists and interdisciplinary scientists.

The SWG, in concert with the NASA Ames Center project team, will now help to guide the detailed definition studies for the observatory and its instruments.

SIRTF has a high scientific priority within NASA. According to Dr. Burton Edelson, NASA Associate Administrator for Space Science and Applications, SIRTF is planned as a 1988 'new start.' "As the discoveries of the IRAS mission have shown us, the field of infrared astronomy is a very rich area for scientific discovery. We have great confidence that SIRTF will produce great science by following up on these important discoveries."

Since SIRTF is designed to detect light in the infrared region of the electromagnetic spectrum, it must be cooled to minimise the amount of infrared (heat) radiation emitted by the telescope itself. The optics and interior surfaces will be cooled to a few degress above absolute zero (-273°C). Placing the observatory in space also eliminates the infrared radiation from the Earth's atmosphere.

The reduced background infrared radiation will allow astronomers to study much fainter and more distant infrared sources.

SIRTF will study a variety of objects, ranging from solar system type dust around nearby stars to forming galaxies at the edge of the known Universe. SIRTF's sensitive

infrared observations will advance our understanding of many important astronomical problems. It will build upon the results of the recently-expired Infrared Astronomical Satellite (IRAS), which successfully carried out the first all-sky survey at infrared wavelengths. During its 300 days of operation, IRAS made many discoveries, including seven comets, a ring of solid material around the star Vega and bands of dust around the Sun between the orbits of Mars and Jupiter.

SIRTF will be about 1000 times more sensitive than IRAS and will study a range of infrared wavelengths that extends almost ten times further in each direction (both shorter and longer) than observed by IRAS. The spectral resolution (the ability to discriminate very fine 'colour') will be between 100 and 1000 times that of IRAS. It will also have much greater capability for providing images of infrared sources with fine spatial detail.

SOLAR OBSERVATORY STUDY

British Aerospace is leading an international team in the study of a unique solar observatory spacecraft for the European Space Agency.

The observatory, called SOHO (Solar Heliospheric Observatory), will be placed in a special orbit around the Sun inside that of the Earth's where the gravitational attractions are equal and opposite. The satellite will thus remain fixed on the Sun/Earth line, some 1.6 million km from Earth.

SOHO will make continuous observations of the solar surface, corona and the solar wind. One of its key measurements will be to detect oscillations of the surface. Such measurements, like those obtained on Earth by terrestrial seismologists, will give important clues on the structure of the interior.

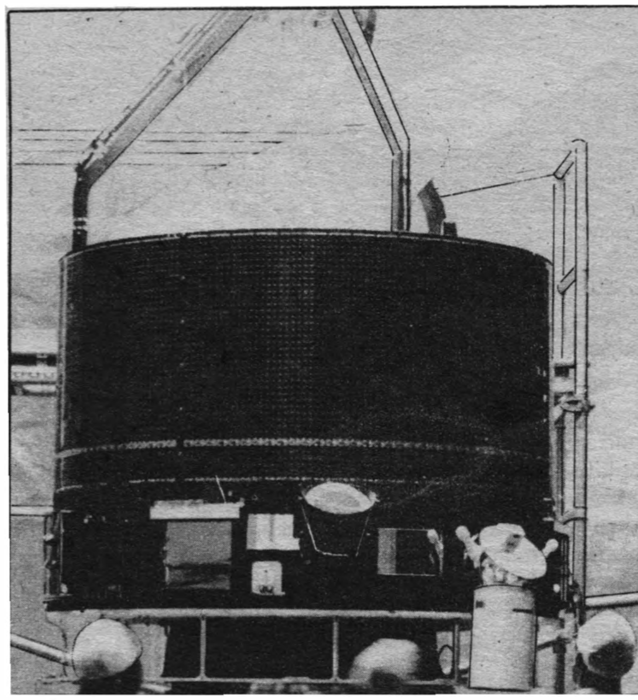
The observatory is planned for launch in 1992 and will participate in an international programme of Sun/Earth studies involving the US, Europe and Japan.

ASTEROID DISCOVERY

A new fast-moving asteroid to add to the 3000 already catalogued has been discovered as a temporary neighbour of the Earth, Venus and Mars. The asteroid, designated 1984QA, was found on 30 August in a path that periodically crosses the orbits of Earth and Venus, and approaches Mars. The gravitational influences of these planets on the 1 km diameter body make its orbit unstable, so 1984QA must be a recent arrival.

Calculations show that the asteroid's close planetary encounters will gradually change its orbit so that sometime during the next 10,000 years it will either hit one of the planets or be ejected from the Solar System completely.

1984QA has a semi-major orbital axis closer to the Sun than that of the Earth (1984QA = 0.989 AU, Earth = 1.0 AU by definition). This places it in the Aten class, named after the first of this type of asteroid, discovered in 1976. This is only the fourth Aten known. All were discovered by JPL scientist Eleanor Helin during her asteroid search programme sponsored by the World Space Foundation. The asteroid is only very rarely observable from Earth. The time it takes to go around the Sun is so little different from the Earth's one year that the discovery circumstances are repeated only about once every 60 years. While not observed at the time, the asteroid came closest in August 1983, passing less than 6½ million km away.



The European Halley's comet Giotto probe, due for launch next July, is seen being installed in the French Toulouse facility in preparation for a solar simulation test.

1984QA continued to be visible through large telescopes to the end of October and it will become more difficult to observe over the next few years until 1986, when it will disappear from our view. It will not be in an observable position again until around the year 2040. Additional observations are being made while it is still visible in order to determine more precisely its physical characteristics and orbital dynamics. Radiometric measurements made from the Infra-Red Telescope Facility in Hawaii give a preliminary indication that the object may be silicaceous, or similar to the Earth in composition.

COMMUNICATIONS

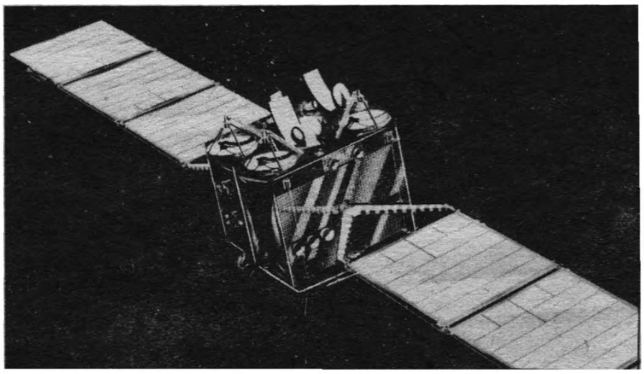
ACTS CONTRACT

NASA has awarded a $260 million contract to a team headed by RCA's Astro-Electronics Division for the design, development and construction of the Advanced Communications Technology Satellite, due for launch by the Shuttle in 1989. A primary goal is to develop advanced satellite communications technologies, including satellite switching and processing techniques and multi-beam satellite antennae, using the 20 and 30 GHz bands. These technologies will be needed for the increased satellite capacity of the mid-1990's.

ECS-2 ACCEPTED

On 12 October 1984 the European Space Agency handed over the ECS-2 satellite to the European Telecommunications Satellite Organisation (Eutelsat). Following its successful launch by an Ariane 3 on 4 August 1984, ECS-2 underwent a number of in-orbit tests before being officially declared operational. Although ESA continues to control the satellite for Eutelsat, acceptance of the satellite will mean that ownership will pass to Eutelsat and the satellite will then be re-named 'Eutelsat I-F2'.

The satellite was brought into service on 1 November. The regional European system was thus completed, with two operational spacecraft in orbit (Eutelsat-F1 was laun-



ECS-2 is now operational.

ched in June 1983). Services include TV distribution to cable networks, telephony, data transmissions and the Satellite Multiservice System (SMS), a system of international links for business services in which the Eutelsat space segment combines with the international space segment of Telecom 1. With SMS, Eutelsat is offering a variety of links in Europe for video-conferencing, high-speed data transmissions, fast facsimile and remote printing.

The European Broadcasting Union (EBU) is using two transponders for the services it provides to its members as part of Eurovision.

The ECS series evolved from ESA's successful experimental satellite OTS (Operational Test Satellite), launched in 1978. They will provide communication services until the early 1990's and ESA is already studying more advanced systems. The third ECS might be launched next August on another Ariane rocket.

SOVIET EARTH STATIONS

Two Soviet coast Earth stations began operations with the Inmarsat international maritime satellite communications system on 17 October 1984. The stations, located at Odessa on the shores of the Black Sea, will provide high quality communications links between ships, other maritime facilities such as offshore drilling rigs and the international telecommunications network.

Owned and operated by Morsviazsputnik, the Soviet Signatory member of Inmarsat, each has a 13 m parabolic antenna, transmitting at 6 GHz and receiving at 4 GHz. One is focused on the Marecs, a satellite operated by Inmarsat in geostationary orbit 36,000 km over the Atlantic Ocean. The other uses facilities aboard an Intelsat 5 satellite over the Indian Ocean. The coverage of the Odessa stations, the first two co-located antennae in the Inmarsat system, therefore extends to almost two-thirds of the Earth's surface.

SPACE SHUTTLE

SHUTTLE TANK DELIVERED

The first Shuttle External Tank for use at the Vandenberg Air Force Base in California arrived in late October after an 8,000 km journey, marking a major milestone in the activation of the West Coast space launch complex. The first launch from there is expected next October.

Most of the major facilities at Space Launch Complex 6 have been completed, including the facility for storage and preparation of the Tank. The US Army Corps of Engineers has been responsible since 1979 for building and facility construction while Martin Marietta Aerospace has had responsibility since 1975 for design, procurement, installation and checkout of Shuttle ground support systems.

The ground support systems consist of 13 new or modified groups of facilities. Major structures, besides the Shuttle Assembly Building, include a launch control centre, payload preparation facility, a mobile tower to take payloads to the vertically-mounted Orbiter, an access tower for the mounted Orbiter and a mobile service tower for access prior to liftoff.

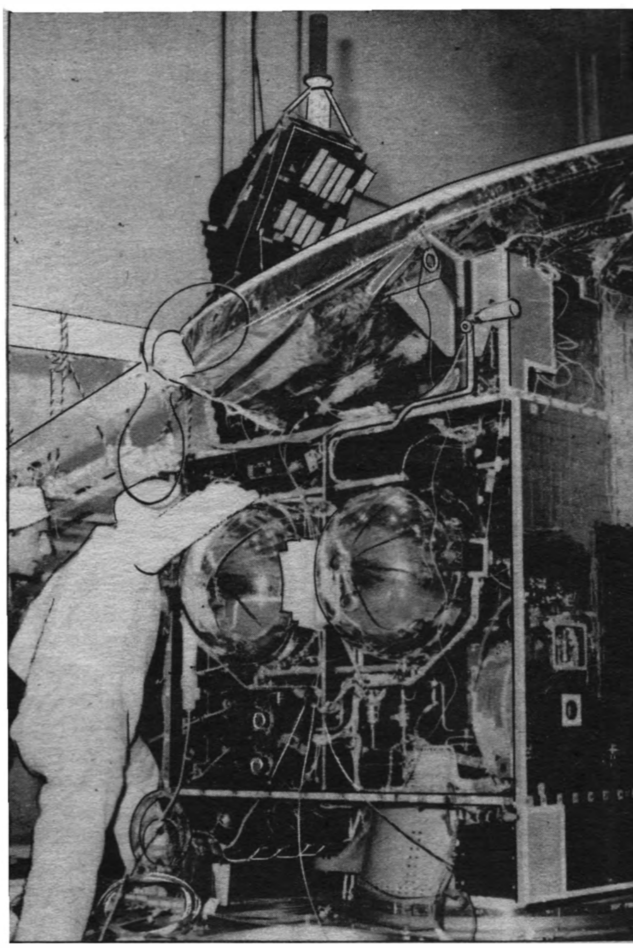
For its journey to Vandenberg, the Tank was mounted on a transporter at Michoud in New Orleans and shipped on a covered barge formerly used to tow Saturn segments to the Kennedy Space Center in Florida. It will be mated with two inert Solid Rocket Boosters and the Orbiter *Enterprise* for compatability testing.

SHUTTLE UPPER STAGES

The Orbital Sciences Corporation in the US are developing a series of four upper stages for use with the Space Shuttle, writes Nicholas Steggall. Based on a modular design, the stages are designed to give increased performance, high reliability and low cost using space-proven hardware. The four stages are: the Transfer Orbit Stage (TOS), a shortened version (TOS-S), the Apogee and Maneuvering Stage (AMS), and a two stage combination vehicle (TOS/AMS).

The TOS, TOS-S and AMS will boost satellites from low altitude 'parking' orbits of the Shuttle to higher orbits,

The Spacenet 2 communications satellite was launched by Ariane VII in November, together with the Marecs B2 maritime communications satellite. The 1995 kg Spacenet and 1050 kg Marecs were both successfully sent into geostationary transfer orbit by the second Ariane 3 launch. *RCA*



such as the elliptical transfer orbit leading to a final geostationary orbit used by communications satellites. The two stage TOS/AMS will be able to place satellites into elliptical transfer orbits, circularising the orbit and changing its orbital plane when final orbital altitude is achieved. The TOS will be ready for its first flight by November 1986, TOS/AMS by April 1987 and the AMS by mid-1987.

ISRAELI SPACE PROGRAMME

The Government of Israel recently formed the Israeli Space Agency (ISA) to plan and implement a series of space projects, writes Joel Powell. In the short term, the Israelis will fly a life sciences experiment involving a hornet's nest aboard the Shuttle by 1985. ISA also intends to fly an Israeli-made astrophysical X-ray sensor aboard NASA's Spartan platform from the Shuttle within the next few years. In the long run, plans include a low Earth orbiting satellite by 1988 to carry environmental and Earth resources instruments. By 1993 ISA hopes to develop a weather satellite and communications satellite (or at least to buy several transponders on a foreign spacecraft). ISA would also like to develop a national satellite launcher, but this is by no means certain.

ASTRONAUTS ASSOCIATION

Following discussions at a meeting in July, the astronauts of Western Europe have formed an Association of European Astronauts (AEA). The declared aims are to encourage meetings for the exchange of views on their training experience and the projects concerned. All European astronauts who have either flown or have been selected to train for a specific mission are eligible to join. The first working meeting was scheduled for 5/6 October 1984 in Maastricht, The Netherlands.

The AEA began with seven members; three ESA astronauts, Claude Nicollier, Ulf Merbold and Wubbo Ockels; two French astronauts, Patrick Baudry and Jean-Loup Chrétien; two German astronauts, Reinhard Furrer and Ernst Messerschmid. Ulf Merbold has already flown on the Shuttle during the first Spacelab mission and Chrétien was on the Soviet Soyuz T-6/Salyut 7 mission. The others are assigned to flights that will take place during 1985. In addition, new members from Italy and Britain are being invited to join the association.

During the working meeting it was planned to discuss plans for Europe in manned space flight, including Columbus, ESA Long Term Planning, US Space Station and German Spacelab preparation.

MATTINGLY LEAVES NASA

Astronaut Tom Mattingly has been named as the Director, Space Program of the Naval Electronic Systems Command, effective early next year, NASA and the US Navy have announced. Becoming a NASA astronaut in April 1966, he flew as command module pilot of Apollo 16 in 1972, and as commander for STS-4, the fourth Shuttle flight, in 1982.

NASA Administrator James Beggs said of Mattingly: "America's civil space programme has profited immensely from having on tap the skill and expertise of military career people like Ken."

October 1984

8 NASA has tentatively given approval for the Galileo probe to fly past an asteroid on its way to Jupiter. A final review still has to be made. Launch is due by Shuttle/Centaur in May 1986.

8 NASA has submitted a new Shuttle pricing policy to the President for approval. Until Oct. 1988, they will charge $71 million for a full cargo bay and after that might charge up to $100 million.

8 China will now launch satellites for other nations on a commercial basis, it is reported. The new liquid oxygen/hydrogen booster, Long March 2, comparable to the US Delta, can handle 400 kg into geostationary orbit from the new launch centre in the southwest at 28°N/100°E.

8 British Aerospace is leading a team of companies in studies for the European SOHO solar obseratory satellite.

10 Astronomers have directly photographed the rings of Uranus for the first time. Using a charge-coupled device camera and image processing, they were found to reflect only 2% of incident sunlight, making them the darkest known objects in the Solar System.

11 The second NOVA US Navy navigation satellite is launched by Scout from California.

12 Iran becomes the 41st member of Inmarsat, the maritime communications satellite agency.

13 Shuttle *Discovery* lands at Kennedy Space Center, Florida at end of mission 41G. The imaging radar experiment might be reflown because of 60% lost data. The Large Format Camera appeared to be completely successful.

16 The 4 m Anglo-Australian Telescope in Australia reaches 10 years of operation.

20 Astronomers have photographed a disc of material around the star Beta Pictoris.

21 The first Space Shuttle External Tank arrives at the Vandenberg Air Force Base in California for the first launch into polar orbit, due next October.

22 The orbits of the Palapa and Westar satellites are being lowered using onboard thrusters for the Shuttle rescue mission in November.

22 The US Congress has approved $15 million funds for the USAF to study a new expendable booster to supplement the Shuttle. Possibilities are now Titan and Atlas Centaur versions, and a new vehicle based on the Shuttle solid boosters.

22 A new asteroid, 1984QA, has been discovered in an unstable orbit crossing the paths of Earth and Venus.

25 A countdown demonstration test is concluded for Shuttle 51A (*Discovery's* second flight).

29 NASA's second TDRS communications satellite is due to be delivered on 8 Dec. for launch next Feb.

31 It is estimated that space losses this year (including the Palapa, Westar and Intelsat 5 communications satellites) have cost insurers $300 million.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

TWENTY YEARS IN SPACE

British Aerospace embarked on its journey into space 20 years ago. The Company's heavy launcher, Blue Streak, was establishing its faultles series of firings and, in 1964, the Company received its first satellite contracts - for the design and construction of the first all-British spacecraft, Ariel 3 (launched in 1967) and for the first scientific spacecraft of the European Space Agency, Esro 2 (Launched in 1968). Both were designed to collect scientific data in space for one year, but went on working long beyond their design lifetimes. As BAe looks ahead to the next 20 years, it is timely to review what might come about with two major projects.

Introduction

In the two decades of its space career, British Aerospace has been the prime contractor for 13 launched communications and scientific satellites without a single failure in orbit. The company has also been involved as a major subcontractor in 27 other satellites that have been launched for scientific and communications purposes, again without a single failure in orbit.

Today, in the ever-expanding world of space communications, reliability, performance and cost are of prime importance to those who buy satellites, those who operate them and those who use them. Twenty years of designing and building satellites of increasing mass, power and complexity, exploiting new technologies and employing an ever-widening range of sophisticated test facilities has put BAe into the position of European leader in space communications and the chosen supplier of European commercial communications spacecraft.

Space Platforms

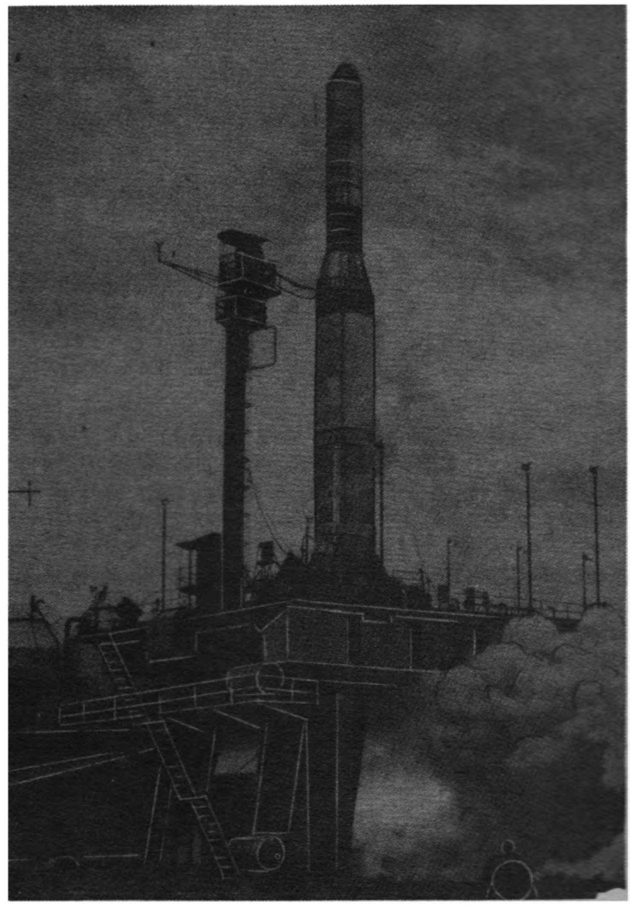
Designed to operate in conjunction with the NASA manned Space Station of the 1990's, the BAe Space Platform would provide a wide variety of unmanned missions at Space Station altitude. It would be taken into orbit on a single Shuttle launch for manned assembly *in situ*.

The unmanned platform is proposed as a key element for European participation in the US Space Station programme. Analysis of operating costs indicate that launch and facility costs for payloads attached to the Platform will be about half of those for payloads flown on retrievable carriers such as Eureca or multi-mission spacecraft.

The Platform will be a multi-user facility, offering power, cooling, data services and orbital control in a contamination-free environment with very low residual accelerations, unaffected by the presence of man. In orbiting in proximity to the manned Station, it will take advantage of manned operations for servicing and payload exchange.

As a permanent facility, it will offer the advantages of requiring only the launch of payloads for different missions, avoiding the need to launch complete spacecraft. Payload retrieval costs will be reduced as well. Again, being a permanent facility, it will not suffer periods of inactivity during which the support equipment of retrievable spacecraft has to be serviced on Earth.

In orbit mass would be around 11 tonnes, with an array width of 54 m providing 35 kW at beginning of life with 12 kW available to the payloads and a thermal rejection capability of 15 kW. Operating altitude can vary from 400 to 800 km. Six berthing points on the 16 m long payload beam could carry up to six full pallets, each containing about 4000 kg of mixed payloads.



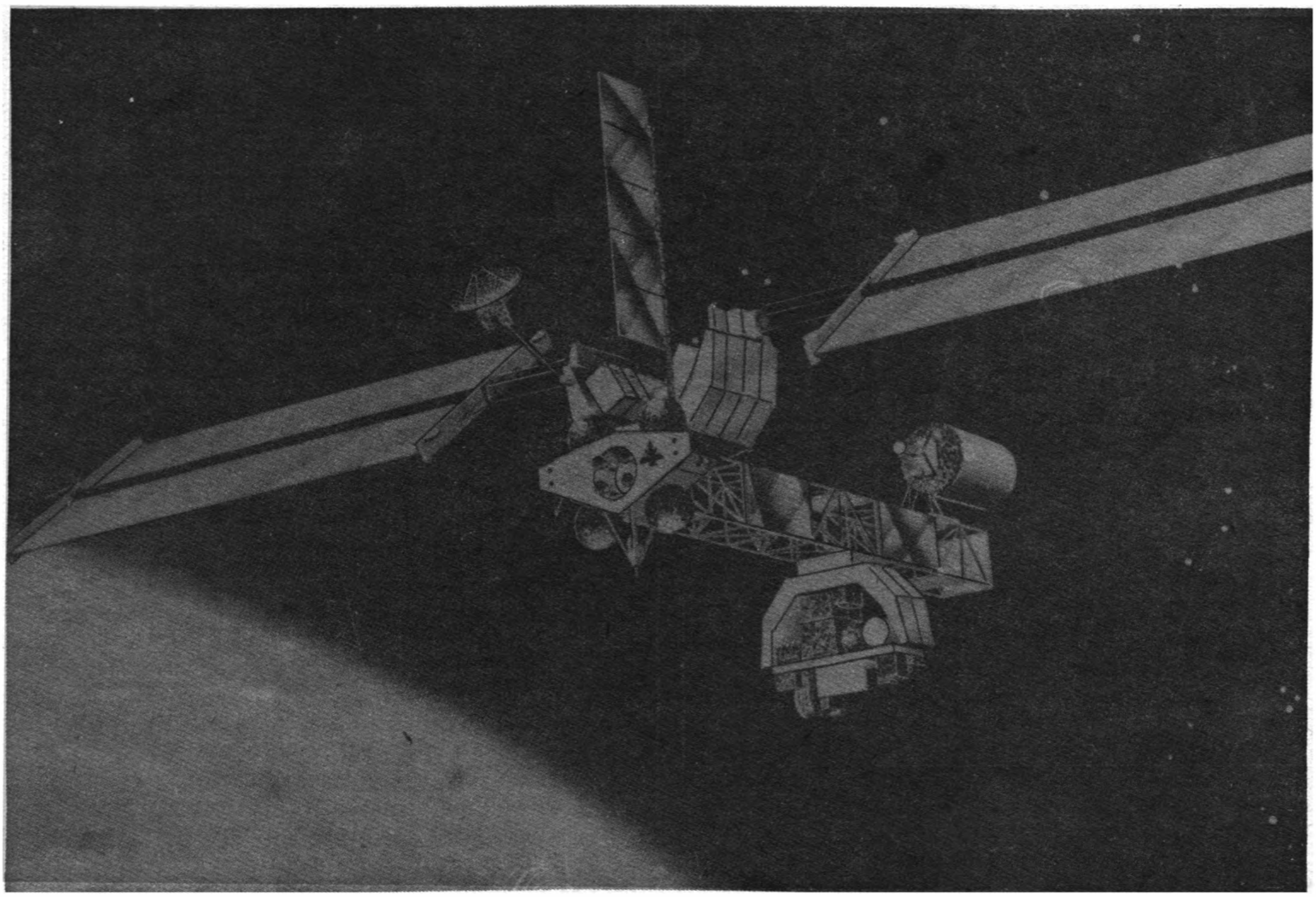
Blue Streak as the first stage of Europa.

Communications

British Aerospace, with its partners in Europe and Canada, is now building Olympus 1 for ESA. This satellite will be the precursor of the Olympus class, the most powerful communications satellites in the world. Olympus 1 will generate 3.5 kW from its solar arrays to provide a variety of broadcasting and telecommunications for Europe in the Ku and Ka bands. Later versions will develop up to nearly 8 kW of power that will enable the satellite to offer up to 12 full power direct TV channels for the US or up to 100,000 telephone circuits or their data equivalents.

Olympus is based on the classic three-axis stabilised form of spacecraft, exemplified by the British Aerospace OTS, ECS, Marecs and Eurostar classes and by the communications satellites of most other world manufacturers. When DC power requirements reach 4 kW, spinning satellites become too large; three-axis stabilised craft can reach up to 8.kW. An input of 8 kW means that about 5 kW must be dissipated as waste heat (because of the inefficiences of the electronic equipment carried inside the body) and the three-axis body can dissipate this heat only through the two faces that do not 'see' the Sun - 'north' and 'south' faces on which the solar arrays are mounted. The size of these faces are constrained by the capacity of launchers.

It is this limitation that has led to the form of spacecraft that will be required in the 1990's and into the next century, before the huge space stations of that century come into being. British Aerospace believes that the basic



The British Aerospace Space Platform could be launched by a single Shuttle.

concept must change - neither the three-axis nor the spinner will be able to handle the ever-increasing traffic demands through each orbital 'parking slot,' but at the same time the new satellites must still be capable of being lifted into orbit by future launchers.

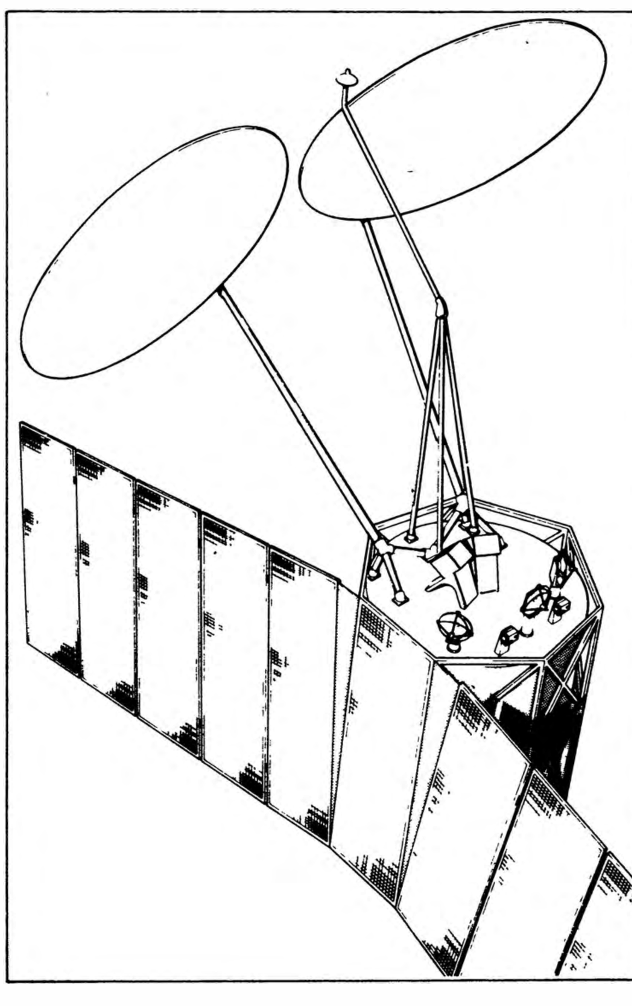
Unlike today's conventional spacecraft, the body of the 'Big Communicator' locks permanently towards the Sun. The first change, therefore, is that there are no rotating bearings and power transfer devices between the body and the solar arrays.

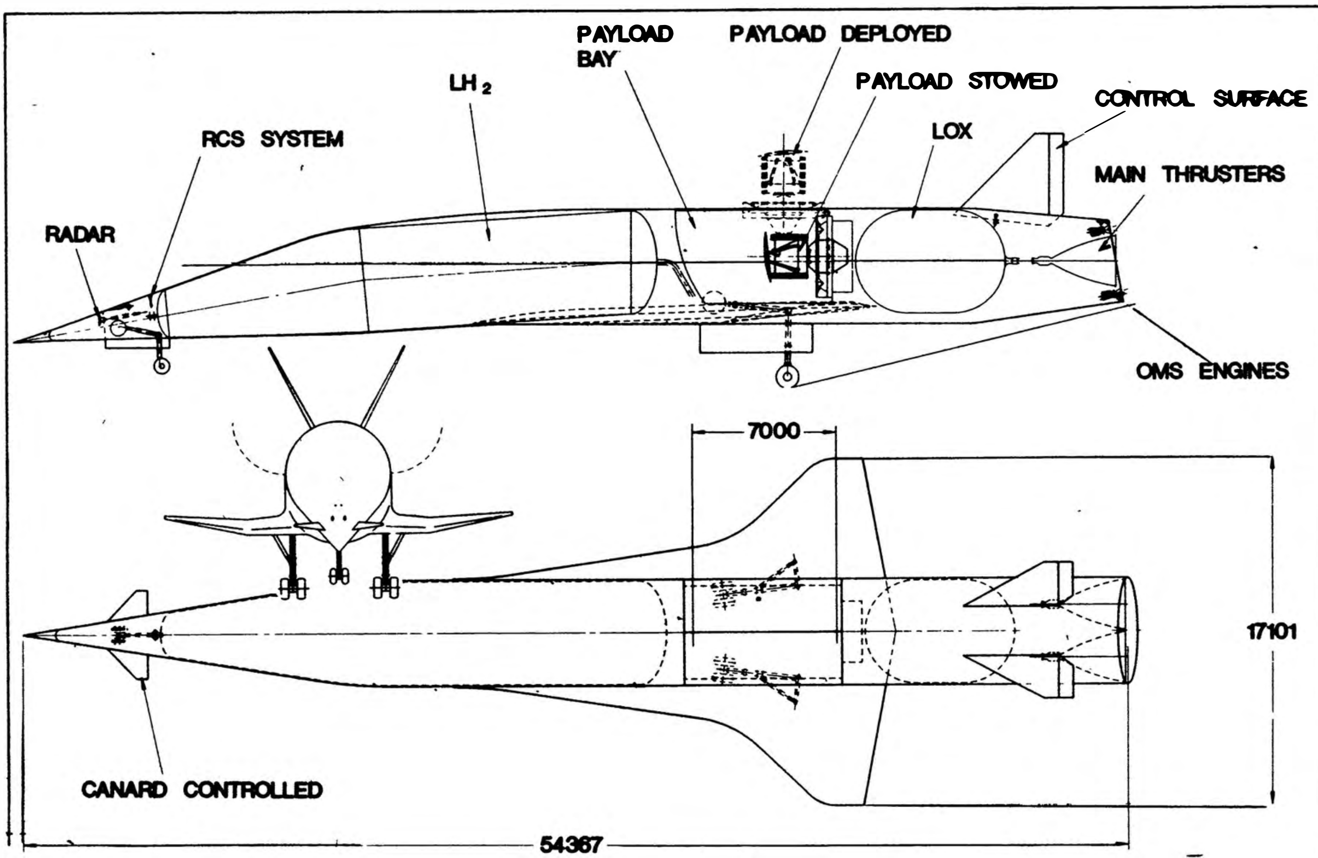
The body itself consists of an open framework, into which is inserted a drum that rotates once per day. This drum, mounted on a bearing, carries all the antennae and communications equipment for the mission and is locked towards the Earth.

The principal advantage is that of thermal capacity. Unlike spinners and conventional three-axis designs, the Big Communicator puts the payload drum permanently in shade. Thus, for a given volume of spacecraft, more heat dissipation can be handled from a larger payload. In comparison with today's satellites, the payload/body mass ratio of the Big Communicator shows on improvement of nearly 2 to 1.

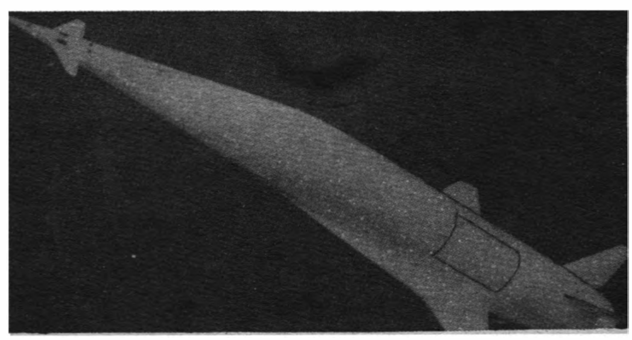
A secondary advantage arises from a reduction in the number of bearing and power transfer assemblies from two to one. The one that *is* used has to carry only the power associated with the payload and not the additional power required by the satellite body.

Adjacent column: A Big Communicator showing the body and arrays locked onto the Sun. The body has an open structure containing a drum that rotates once per day and radiates excess heat from the payload through its structure. The communications equipment, antennae and inter-satellite links are mounted on the drum. The arrays are given "anhedral" to provide a clear line of sight for the antennae when they are looking along the plane of the arrays and for balancing torques.





The British Aerospace Hotol concept, capable of handling up to 7000 kg to low Earth orbit in its 9 x 4.5 m cargo bay. Rolls-Royce are contributing to the propulsion studies. (Dimensions in mm).



The open-framed body is seven sided, one to act as the mounting face for the arrays and the others to provide a symmetrical mounting for the wrap-around array panels. The number of panels can be varied from six (three on each side) to 22 (11 on each side) to provide a DC power range from 4 kW to 15 kW. In each case, power in transfer orbit is provided by the central body-mounted array panel and by those wrap-around panels that expose cells when wrapped. In cases where multi-wrapping is used (more than three panels on each side), the total number of panels is chosen to ensure that not less than two panels expose cells when wrapped. Thus, in the maximum case of 22 panels, wrapping occurs four times, but the last wrap contains only two panels, leaving two of the previous wrap exposed.

Stabilisation is achieved by twin momentum wheels with a common axis on the Sun-pointing axis, controlled off-Sun sensors with automatic compensation for variations in Sun angle between solstices. The payload drum is driven off its central bearing, which is controlled by Earth sensors on the drum and by radio frequency pointing when required.

The body carries all the satellite service functions, including attitude and orbit control thrusters, fuel supplies, batteries and telemetry and is configured at its base to mount on to the Ariane 4 or on to a liquid-propellant perigee stage for the Shuttle.

Thermally, the payload drum, which is mirrored and which exposes most of its surface to space at any one time, provides a benign environment for the payload, with increased mounting areas available for high-dissipation elements and for batteries that are sensitive to high temperatures.

The design needs to be flexible to accommodate the various services that the Big Communicator will provide: fixed, mobile and broadcast services. Differences between these three types are seen in the array power and the antenna configurations. The principal difference in comparison with today's satellites will be the use of inter-satellite links in Big Communicator clusters and between clusters. This will permit clusters to be accommodated in orbit above land masses, providing total coverage of those areas, with communications between clusters by carbon dioxide laser links. Thus, the traditional configuration of satellites over oceans to interconnect continents, with the inevitable limitation on continental coverage, will be replaced by laser-linked clusters of Big Communicators over each continent.

Typically, with its improved mass-carrying capacity and with new communications technologies, a Big Communicator will be able to handle ten times the capacity of an Intelsat 5. With it will come other new concepts by British Aerospace:

STV: A new, high-efficiency, liquid-propellant upper stage for Shuttle, to lift satellites of the Olympus and Big Communicator classes from lower Earth orbit to geostationary orbit.

HOTOL: A new concept for a Horizontal Take-Off and Landing launcher which will provide more efficient and more economic means of launching than today's vertical take-off rockets (described in detail in November 1984's *Spaceflight* 'Space Report' section).

The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

COLOURS OF INFRARED STARS

The ancient Greek astronomers Hipparchus and Ptolemy arbitrarily graded the visible stars into six brightness classes in their two famous catalogues. The stars in the sixth class were just barely visible to the naked eye, while the 20 or so brightest stars occupied the first class.

Nineteenth century astronomers quantified this classification and defined a first magnitude star to be 100 times brighter than a sixth magnitude star. Now, it is a curious physiological fact that the human eye converts equal *ratios* of brightness into equal *intervals* of perceived (psychological) intensity. So, since there is a difference of five magnitudes between a first magnitude star and a sixth magnitude star, each magnitude class is brighter than its neighbour by a factor equal to the fifth root of 100, or approximately 2.5 Thus, a first magnitude star emits about 2.5 times more photons per second than does a second magnitude star.

Modern astronomy has extended the concept of stellar magnitude in two directions: (1) to include stars fainter than sixth magnitude (and, also stars brighter than first magnitude; Sirius has a magnitude equal to *minus* 1.4), and (2) to measure the brightness of a star at different colours.

With regard to extension (1), Halley's comet was recovered with the 5 m telescope at Palomar in 1982 when it was a very faint object, at magnitude 24.3, which is more than 20 million times fainter than one of Ptolemy's sixth magnitude stars.

Ptolemy did make a comment in his catalogue on the colours of six stars, calling them *hypokirros,* or yellowish. Modern photometric techniques employ filters of various colours, i.e., filters that pass only selected wavelengths of light and then measure the magnitude of the star in question at that colour. By comparing the magnitude of a star at one wavelength (colour) with its magnitude at another, the star can be better characterised than by quoting a single magnitude to represent it.

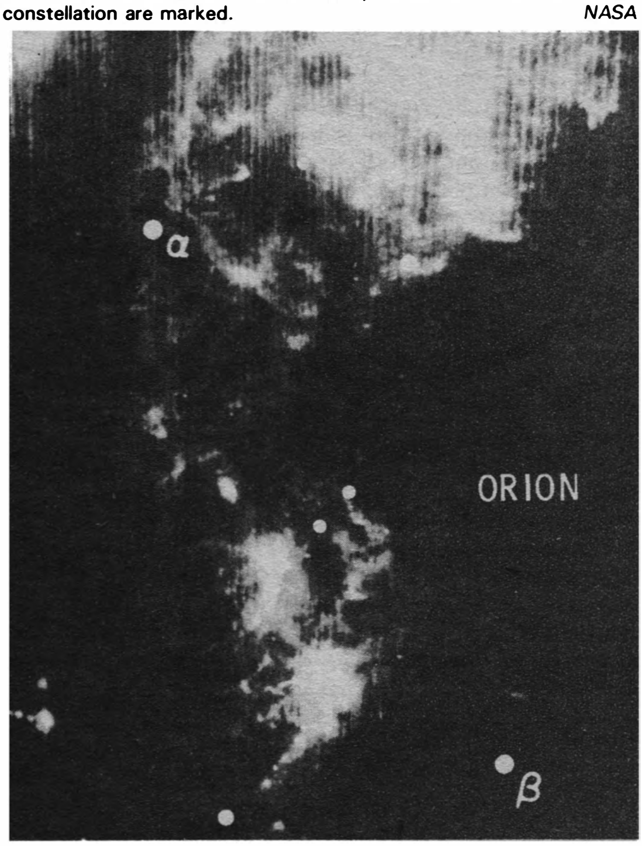
During its 10 month mission in 1983 to survey the entire sky at infrared wavelengths, the Infrared Astronomical Satellite (IRAS) catalogued some 250,000 stars, measuring both their positions and brightnesses at several wavelengths (colours). Visible light extends from a wavelength of about 0.4 microns to 0.7 microns (a micron is one millionth of a metre); IRAS recorded energy in the infrared region from 8 microns to 100 microns.

Dr. George Aumann of JPL and a member of the IRAS flight team in England was making what he describes as some 'rather mundane' measurements on 10 stars that were being used for inflight calibration purposes. During this activity he noted that the star Vega was considerably brighter at 60 microns than expected. Intrigued, Aumann and his colleague Dr. Fred Gillett of the Kitt Peak National Observatory examined in detail the immediate region about Vega. The rest is history (see the December 1983 edition of this column).

They found that Vega possessed an extended structure about it on the order of 100 astronomical units in diameter. Calculations showed that this structure consisted of particle-sized objects rather than mere dust or gas. It could not be determined whether or not planets are present in this cloud of material. Later, a second star, Fomalhaut, was also found to have particles orbiting about it (see 'Space at JPL' in the April 1984 issue). Fomalhaut is also brighter at 60 microns than it is at 12 microns, due to the cooler, orbiting material; cool objects like particles emit longer wavelengths than hot objects like stars.

With these examples in mind, Aumann searched the IRAS data, recording the difference between the magnitudes of stars at 60 microns and at 12 microns and concluded that 10% to 20% of nearby main sequence stars are at least one magnitude brighter at 60 microns than they are at 12 microns. Vega was two magntidues brighter between these two infrared 'colours.' One star, Beta Pictoris, was over five magnitudes brighter at 60

The Orion Nebula as seen in infrared by IRAS. The main stars of the constellation are marked. *NASA*



microns. The term 'main sequence star' is an astronomical classification that distinguishes these stars from the so-called 'red giant or supergiant stars.' Our Sun is a typical main sequence star.

No extended structures have been determined to exist around these stars with infrared excesses at 60 microns other than, of course, Vega and Fomalhaut. However, the phenomenon is suggestive and Aumann speculated at an International Astronomical Union meeting in Boston in July that the infrared excesses could be indicative of a certain stage of stellar evolution. It is possible that a small-particle stage could precede the production of planets; theorists presently believe that it took our Solar System a few hundred million years to accrete its outer planets. (The Solar System, if observed from afar, would not show a significant infrared excess, because the planets, compared to a swarm of small particles, do not have sufficient surface area to be detected in this way).

Further observations and analysis must be conducted before the evolution of other stellar systems can be understood; but see Paul Weisman's interesting conclusions about possible comets around Vega, as reported in the November 1984 issue of this column.

If the 10-20% of the stars with infrared excesses do eventually prove to be protoplanetary systems, Aumann concludes that, logically, the places to look for planets would be those main sequence stars that do not exhibit excesses, i.e., stars that have, possibly, already given birth to their planets.

HERSCHEL, URANUS AND INFRARED

In 1781 the musician and astronomer William Herschel (1738-1822) made the first addition to the set of six planets known since prehistory. Observing from his residence in Bath, England, he discovered the planet that eventually came to be known as Uranus.

Herschel detected its non-sidereal nature by the existence of a sensible disc and a subsequent motion from night to night. Writing in the *Philosophical Transactions* of the Royal Society, he describes the process of discovery: 'On Tuesday the 13th March, between ten and eleven in the evening, while I was examining the small stars in the neighborhood of H Geminorum, I perceived one that appeared visibly larger than the rest...' At this time Herschel thought he had detected a comet, as evidenced by the title of his paper: "Account of a Comet."

In addition to Uranus, Herschel effected the first extension of the electromagnetic spectrum beyond the visible region when he found and explored the infrared in 1800. To accomplish this he split sunlight into its constituent colours using a prism and then placed a thermometer adjacent to the red portion of the spectrum, where no colour was apparent to the eye. The indicated temperature rose above ambient conditions in the room; the infrared had been discovered.

Two current programmes at JPL are directly dependent upon Herschel's discoveries. Voyager 2 is on its way to a January 1986 closest approach to Uranus, and IRAS data are still being analysed after that satellite's all-sky survey in the infrared conducted in 1983.

The City of Bath is a marvel of Georgian architecture and has extensive Roman archaeological discoveries to interest the visitor. However, none of Bath's attractions exceeds in scientific significance the Herschel House and Museum at 19 New King Street. The house itself was built in 1766 and from its garden Herschel discovered Uranus. The William Herschel Society, formed in the City of Bath in 1977, has restored the house and reproduced in its interior the flavour of Herschel's research and 18th century bath.

Herschel was a professional musician and composed for and played the organ in the Octagon Chapel in Bath, as well as performing in Bristol and other towns. A musical display in the Herschel House commemorates this aspect of his life in addition to astronomical and personal memorabilia of Herschel and his sister and colleague, Caroline. Miss Herschel was a musician (singer) and astronomer in her own right. She discovered eight comets and was awarded the gold medal of the Royal Astronomical Society in 1828.

It is a thrill not to be missed by the devotee of astronomy and space exploration to stand in Herschel's garden where the known Solar System suddenly expanded by a factor of two on a winter night in 1781.

THE POWER OF PHOTONS

Potential applications of specular (or mirror) reflection in space missions were examined in the November edition of this column. There it was shown that solar photon management with carefully positioned mirrors could transfer information over large distances across the Solar System. The advanced concept review for this month returns to the subject of photons but concentrates upon their ability to exert force.

The physics underlying the use of photons to transmit force relies upon the fact that they possess momentum and that, upon striking an object such as a spacecraft, some momentum gets transferred to that object. In principle, it is no different from transferring momentum from racket to ball in a game of tennis. In space navigation the force of 'solar pressure' exerted by photons from the Sun is significant. If neglected in trajectory computations it would result in errors of thousands of kilometres for interplanetary flights.

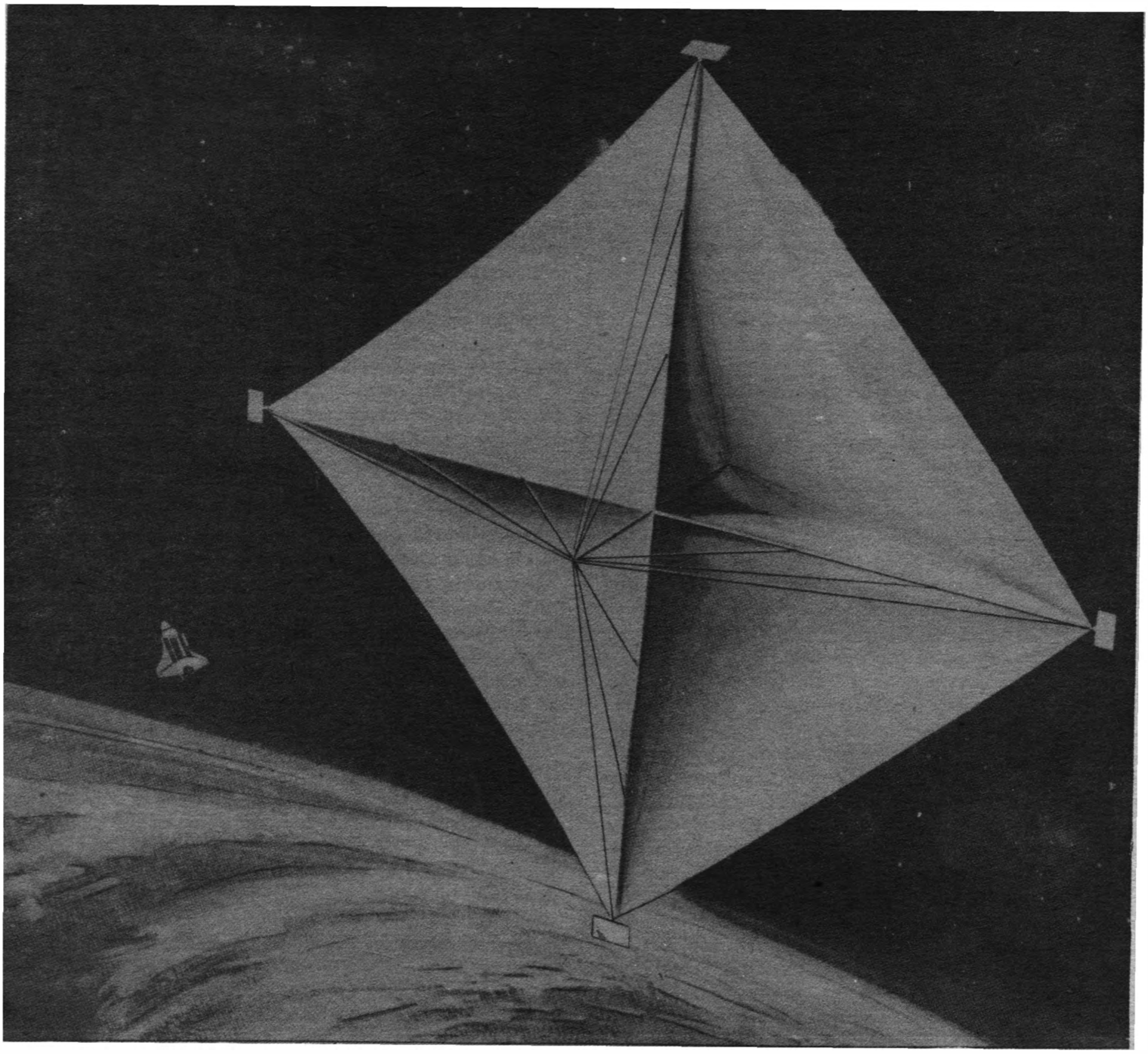
It is possible to use the photons in an active manner to control the attitude (orientation) of certain spacecraft. The Mariner 4 Mars probe and the more recent Insat communications/meteorology satellites of India carried solar vanes. By adjusting the position of these vanes, rotational forces could be generated to control attitude. This method of control reduces or eliminates the usual reliance upon small rocket thrusters for attitude control.

The most successful use of this method occurred during the Mariner 10 mission to Venus and Mercury. Mariner, launched in 1973, was running out of propellant for its attitude control subsystem and so a plan was devised to use its solar panels (normally used only to convert sunlight to electricity) as solar vanes. Without this, it would not have been possible to accomplish the three successful flybys of Mercury.

One of the most exciting applications of solar pressure will be to propel spacecraft: solar sailing. The concept in modern times goes back to 1946 when an Italian, Luigi Gussalli, suggested a variant of what is currently conceived as solar sailing (Tsiolkovsky, as usual, was earlier in thinking of the idea).

The use of a solar sail was seriously considered for a rendezvous with Halley's comet, a mission (never funded) that the Jet Propulsion Laboratory was designing in the late 1970's. However, the solar sail eventually lost out to solar electric propulsion.

Numerous other applications of the solar-sailing technique have been proposed in the literature. For example, Robert L. Staehle has suggested that Solar Sail Cargo Vehicles could play a useful role in a mission to Mars (see his article in the January 1983 issue of *Spaceflight*). The first actual solar sail mission could be the World Space



A 1976 NASA concept for a 700 m square solar sail for Halley's comet.

Foundation's planned engineering development mission scheduled for 1987 or 1988. The primary objectives for the Earth-orbiting mission are to understand the dynamics of the sail and the control of the spacecraft.

Robert L. Forward has proposed an extension of the solar-sail concept that could be applicable to interstellar flight: a sail driven not by solar photons but by a bank of powerful lasers in solar orbit (and drawing their power from the Sun - see the October 1976 *JBIS* for his analysis).

Perhaps the ultimate use of photons for propulsion would occur with the construction of a photon rocket in the more distant future. It certainly would have a high exhaust velocity!

Going beyond photon rockets, one can speculate on the possibility of tachyon rockets. Tachyons are hypothetical particles that travel at speeds greater than that of light (a photon's pace). The nomenclature for particles of various speeds is rather amusing: tardyons (less than the speed of light), luxons (at the speed of light, i.e., photons), and tachyons (greater than the speed of light). Readers interested in the vagaries of tachyons should consult Martin Harwit's book *Astrophysical Concepts* (Wiley, 1973).

ULYSSES MISSION

The International Solar Polar Mission, a joint ESA/NASA project, has been renamed 'Ulysses.' The new name arose as the result of a contest and was the suggestion of Bruno Bertotti of Italy who will be the principal investigator for a gravity-wave experiment on the mission.

The relationship to solar exploration comes from a late medieval tradition which tells of a last voyage of Ulysses beyond Gibraltar into 'an uninhabited world behind the Sun,' as described in the 26th Canto of Dante's *Inferno*. The new name and the Ulyssean traditions of exploration that cluster around it 'could help in framing our technical work in a broader poetical and philosophical background' according to Bertotti.

The unique feature of the Ulysses mission is that it will explore both poles of the Sun from a position far out of the plane of the ecliptic, or orbital plane of the Earth. Most previous space missions have been confined to a narrow band about ± 7.5° centred on the ecliptic (see 'Space at JPL' in the March 1983 issue). The primary objectives of the Ulysses mission are to investigate, from

its advantageous position, the properties of the solar wind, solar flare X-rays, cosmic gamma ray bursts, the heliospheric magnetic field, the interplanetary magnetic field, cosmic rays and cosmic dust. In addition there will be the previously-mentioned gravity-wave experiment as well as some radio science investigations.

The 370 kg spacecraft was built by Dornier Systems of West Germany and is currently in storage at the ESTEC facility in Noordwijk, The Netherlands. It entered storage in December 1983, resulting from a delay in the original launch date of 3 February 1983. It will be removed in March 1985, when it will be re-integrated with the scientific instruments which are stored separately at the institutions of the principal investigators.

After launch in 1986 from a Shuttle/Centaur G' combination, Ulysses will first head to Jupiter in order to receive a gravity assist that will fling it far out of the ecliptic and in a direction back toward the Sun. The first solar encounter will begin when Ulysses reaches 70° solar latitude, in either October or December 1989, depending on the final trajectory chosen. It will spend about four months above that latitutde at a distance of just over two astronomical units from the Sun (an AU is the mean distance from Earth to Sun: about 150 million km). Polar passage is scheduled to take place in either December 1989 or February 1990, again depending on the trajectory.

Bending down toward the ecliptic, it will cross that plane in July 1990 and begin its climb to the opposite pole which will be overflown in October 1990 or January 1991. The end of mission is 27 March 1991. Whether Ulysses passes the north or south pole of the Sun first has yet to be decided; a south-first polar passage is currently favoured but the final selection may not be made until as late as six months before launch.

Since both Ulysses and NASA's Galileo mission will head to Jupiter in 1986, they must share the 'Jupiter window' for that year. The combined possible launch period for these two missions is contained between 15 May and 8 June, inclusive. Nominally, Ulysses will be launched first. Galileo will become the prime mission for launch on 20 May. Even though the two will go up from different pads at the Kennedy Space Center (39A for Ulysses and 39B for Galileo), a 64 to 112 hour reset period must be allowed between launches for operational considerations, a factor that would assume significance if the Ulysses launch were to be delayed for some reason.

In addition to supplying the craft, four of the nine instruments and elements of the mission design, ESA will lead mission operations (from JPL). NASA will provide the Shuttle/Centaur launch vehicles, part of the mission design, five instruments, the RTG power source for the spacecraft, the operations facility and tracking and navigation functions.

The US project manager for Ulysses is Willis G. Meeks of JPL, and Derek Eaton is the European project manager.

SIMULATING VOYAGER

The Space Flight Support building at JPL (more commonly known to the natives as Building 264) houses, as the name implies, several of the Laboratory's flight projects: Voyager, the Venus Radar Mapper (VRM), the Extreme Ultraviolet Explorer (EUVE), the proposed oceanographic satellite Topex and the Ulysses mission. In the northeast corner of the fifth floor of the building is a large room filled with computers and supporting equipment. The purpose of this apparatus, the Capability Demonstration Laboratory (CDL), is to provide a realistic simulation of the Voyager spacecraft in order to test the effect of new computer programs upon the spacecraft. The CDL allows us to determine whether or not Voyager will respond to its computer instructions as anticipated.

The generation of one one of these computer programs was considered in December's issue (see 'Keeping Voyager Current' p.448). This month the story is continued by looking at the role that the CDL plays in confirming the correctness of new flight software, in particular the software employed in the Flight Data Subsystem (FDS) computer onboard Voyager. Recall that this computer (really 'these computers;' there are two of them onboard Voyager 2) is charged with the tasks of (1) commanding the 11 instruments of the spacecraft in their task of taking scientific data, and (2) processing these data into a form suitable for transmission back to Earth.

The operator of the CDL facility is Stuart de Jesus. After receipt of computer code, on a tape, from the developers of that code, he proceeds to the conduct of his tests. The CDL is operated in two modes. In the first, the full spectrum of supporting equipment is arrayed together with a faithful replica of the computer, which has been loaded with the program or portion of a program that is being tested.

Supporting equipment includes, for example, models of the other two types of computers onboard the spacecraft; the Sun sensor and star tracker which, together, help to keep the spacecraft properly oriented; and the motor and gear train that is used to drive the platform upon which are located several of its instruments, including the two cameras (the platform assemblage is not included in the CDL).

The output of the test is in the form of spacecraft telemetry, i.e., the stream of scientific and engineering data normally sent to the ground. Some of the telemetry is checked by de Jesus himself, some is checked automatically by a controlling computer in the CDL, and some may be turned over to the experts on the Voyager spacecraft team for their evaluation.

If problems are uncovered during this process, then the computer program is referred back to its developers, Dick Rice and Ed Blizzard, for correction. In the case of testing extensive revisions of the computer program it is not unusual to perform several iterations of the test-and-correction procedure.

The second mode in which the CDL is operated, and this is the most frequently invoked alternative, dispenses with the supporting equipment and substitutes in its place another computer. Thus, in this mode the Flight Data Subsystem computer with its resident program-to-be-tested is imbedded in the world as simulated by another computer. One computer creates an illusion to sustain another computer!

As the Voyager spacecraft recede further into the outer reaches of the Solar System, they will need new computer capabilities to assist them in coping with their changing environment. Therefore, it is expected that continued program development and associated testing in the CDL will accompany Voyager to Uranus, Neptune and interstellar space.

Thanks are due to R.J. Rice, E.M. Blizzard and S.R. de Jesus for their tutorial time with regard to these discussions on Voyager. The Voyager project is managed by JPL for NASA's Office of Space Science and Applications. Richard P. Laeser of JPL is the Project Manager.

SPACE GREENHOUSE

Astronauts may one day use the traditional skills of farming in the decidedly unfamiliar environment of space. Boeing Aerospace Company researchers are now studying design concepts under a $95,000 NASA contract for a Space Station greenhouse that would allow astronauts to grow their own food.

Introduction

Manned space flights to date have used two methods of supplying their occupants with water, air, waste management and food: storing all consumables onboard before the initial launch and holding all of the waste products as they are generated, and resupplying consumables *via* transportation vehicles and returning the waste products (much as the Progress craft do with the Soviet Salyut space station).

A biological regenerative closed system would supply all essential materials by recycling waste products back into reusable materials. A study completed for NASA in 1983 examined the initial cost and feasibility of transporting a Controlled Ecological Life Support System (CELSS) to be used aboard a spacecraft or a remote land base, such as a lunar station. The current study being undertaken by the life sciences group is examining the actual concept design of such a system.

The Greenhouse

What form would a CELSS greenhouse take and what could be grown and harvested in such a unique environment? Mel Oleson, a life sciences analyst with Boeing, says that several designs are being studied. Each must take into consideration power, mass, volume, cost, reliability, maintainability, accessibility, training ease and safety. But can large quantities of vegetables be grown in zero gravity or a partial gravity state? Oleson admits there are no guarantees.

"We think that some plants will grow in zero gravity and that some will grow in partial gravity," he said, "but until actual experiments are conducted we don't know for certain whether any sustained growth will occur in those environments."

Meanwhile, a list of plants that might reasonably fit their criteria for an operational space greenhouse is being developed.

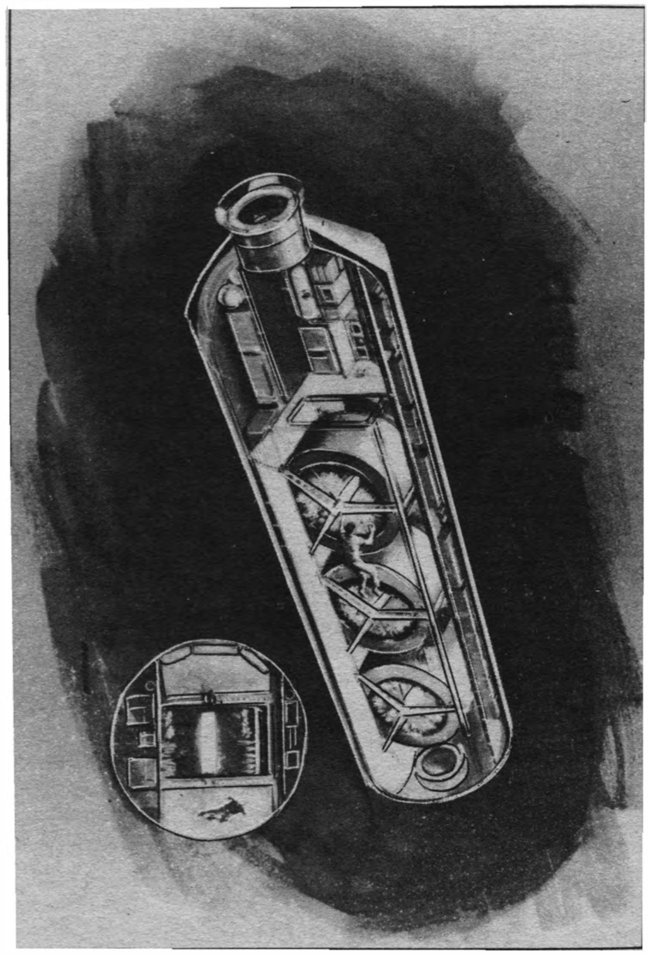
The Soviets, he noted, are rumoured to have experimented with their own 'space garden' of onions, tomatoes, marigolds and celery.

A Space Station astronaut's diet composed entirely of products from a CELSS greenhouse would obviously be vegetarian, though the process, which starts with the planting of a seed and ends with consumption of the grown product, is an involved and complicated one.

"After we decide what we will grow, then we ask, 'Do we grow seeds in space, or do we use cuttings or cloning?" Oleson wonders. "That is a bioengineering research question."

Plant growth systems is next on the list of questions to be answered. Growth might require periods of simulated gravity, such as that provided by a rotating drum system, while light might be optimised by the use of cylindrical plant trays surrounded by fluorescent lamps.

Researchers are designing prototypes for a food processing centre where harvesting and washing could be accomplished. Methods of harvesting would differ; a picking sequence for food such as strawberries would



This concept of a pressurised Controlled Ecological Life Support System shows how rotating drums would simulate gravity to grow plants in space. A light source is shown in the middle of each drum. In the circular drawing, a cutaway of one of the drums is depicted with plants growing in the interior. *Boeing*

need to be devised while plants such as wheat would need to be mass harvested.

Nothing would go to waste in the process. Waste products (human, plant and inorganic) would be recycled into a nutrient solution used to feed the plants.

Once the plants have been harvested they would have to be stored on a long-term basis. "We're looking into traditional freezing, dehydration and dry and wet storage techniques," Oleson said.

Solar panels extended from the growth module would power artificial lighting of the support system. Water and oxygen would be recycled by biological processes. Plants give off oxygen, which would then be used to resupply the air in the closed environment.

In a system in which 97% of a person's needs is supplied by the greenhouse, such a diet might include the following plants: lettuce, tomatoes, carrots, cabbage, potatoes, green beans, dry beans, wheat and melons. Other plants that could be considered include soy beans, mustard greens, peanuts, rice, corn, kale, turnip greens, chick peas, oats and broccoli.

A permanently occupied Space Station holding four people and operating for longer than six years, regenerating 50% of the diet, would appear to be less costly than resupplying the required food and oxygen and storing the waste products.

A Space Station operating more than eight years could economically produce 97% of the diet rather than resupply an equivalent amount of consumables. The initial research project estimated that a savings of at least $68 million over a 15-year Space Station lifetime could be realised.

PERSONAL PROFILE

ERIK QUISTGAARD

The previous Director-General of the European Space Agency, Erik Quistgaard, held the post from May 1980 to August 1984. His tenure at ESA saw the Ariane rocket reach operational maturity and Spacelab establish itself as a valuable contributor to space science.

Introduction

Since Man first looked up at the heavens and wondered, space has been a challenge. But without vision, without the faith to turn dreams into reality, space cannot be conquered. The dreams are many and they are individual to each of us, often depending on our early experiences. For me, such dreams go back as far as I can remember.

Born in Copenhagen, I spent my first six years with my family on the top floor of an apartment building. Every day, as I looked out of the east-facing window, I could see flying machines taking off from a nearby airport. Even today I can sense the thrill and excitement a small boy experienced as he watched those tiny biplanes perform all kinds of loops and other daring manoeuvres. Through the other windows to the west, I looked down on the harbour and the ships unloading their cargoes of coal, timber and other goods from all over the world. I could visualise the many countries of origin as the docks swarmed daily with sailors from China, Africa and other far-off places.

Then, at the age of six, I was suddenly transplanted into the fertile Danish countryside of Southern Jutland. The day that I found my father's 1928 Chevrolet parked unattended in the courtyard is still vivid in my memory. Of course, like any normal boy, I climbed in and took my place behind the wheel, pretending to be the driver. As I stamped my foot down, I hit the starter button and, to my utter astonishment, the motor roared into life and the car began to move. I had not realised that my father had

Mr. Quistgaard meets Mrs. Thatcher at ESTEC in September 1983. *ESTEC*

Mr. Quistgaard with Her Majesty, Queen Beatrix of The Netherlands at the celebrations in May 1984 to mark 20 years of European space cooperation. *ESTEC*

left the keys in with the ignition on! Fortunately, I had watched carefully when he had taken me for rides, and after some yards of dreadful driving I managed to stop. I had received my first lesson to the effect that, with the right know-how and techniques, man can control complicated technical machines and processes.

It is little wonder then that, as a young engineer, I was designing cars at the Chrysler works in Detroit and later at Volvo in Gothenburg, where I was fortunate enough to be one of those who helped to build up that company at the beginning of the 1950's. Being in on the ground floor gave me a very useful insight into how a technically-based company grows and operates. I was able to use that knowledge later in a totally different field: ship building. In 1973 we grossed 1.6 million tonnes deadweight (tdw) from one dock, a success born of good systems concepts and good engineering practices. In 1975, however, the world shipping slump arrived and large vessels were no longer in demand. In one jump we went from ships of 500,000 tdw to 500 tdw each. By technical know-how and a strong control over operations, such changes can be made.

Then the Danish Delegation to ESA asked me if I would be willing to take on the challenge of European space cooperation. Fortunately for me, the other Member States of this fine organisation followed suit.

Head of ESA

So, in May 1980, I started in Paris, only five days before the second experimental Ariane rocket fell into the sea. I, too, had been dropped in at the deep end! It was not long before I realised that the real challenge lay not only in continuing the European space effort but in giving it new momentum. My first and very difficult task was to understand what it was all about: the mechanics of space, the physical conditions for satellites and launchers, what was needed to guide and control spacecraft and their launchers, how to get the instruments to work and how to transmit the signals. Then there were the unusual

aspects of space technology: how to achieve reliability for something that is subjected to the space environment for years without the possibility of maintenance or repair; how to preview and develop technology for space engines that are not yet conceived and will be produced only in 5 to 15 years' time. All these technical considerations are beyond the capacity of one brain alone to accommodate.

Space, being the domain of dreamers, can be tackled only by people with ideas but it has also to be supported by those with the political will to succeed.

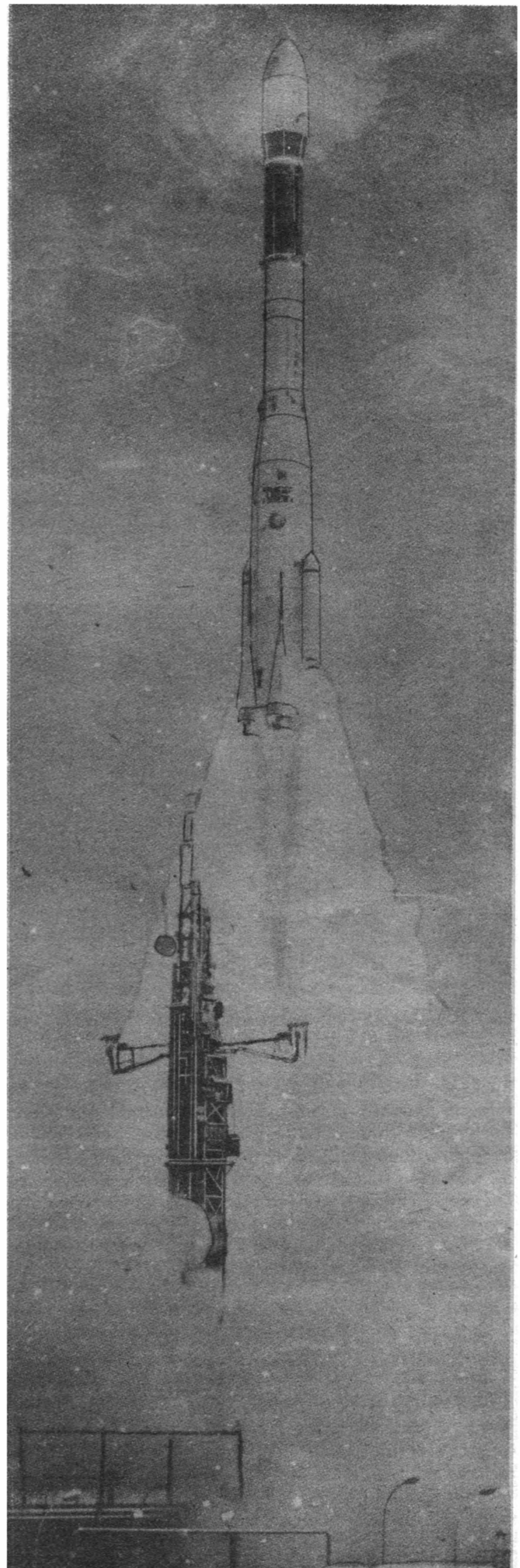
Space costs money and a considerable intellectual output. It is to Europe's credit that it was realised from the beginning that there were critical financial and intellectual thresholds that could only be crossed by concerted cooperation between nations. Here, again, understanding the political objectives of the member states was a 'must.' It was necessary for me and my collaborators in ESA to spend a great deal of time talking to those people in Europe who were politically influential and had an interest in space.

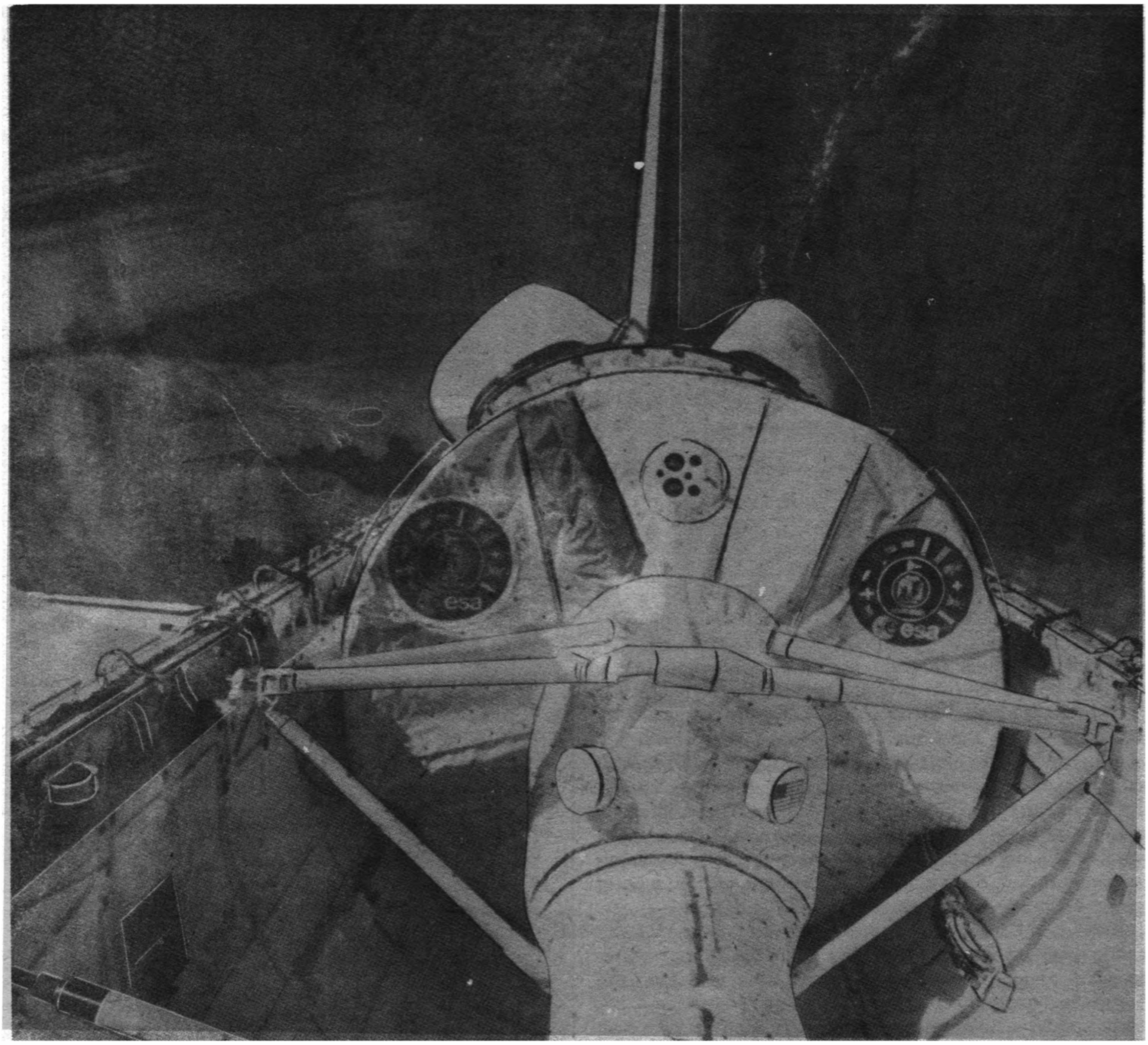
Politicians certainly need technically sound, good and unbiased guidance in such a difficult subject. To be really honest in approach and convincing in argument, one should have a better knowledge oneself. For me, these years in European high technology and in a difficult political environment have been the best of my life. It takes a particular type of person to be a project manager or to have a responsible role in a project, knowing that even after battling through a difficult definition phase there is only a certain probability that the satellite will perform as planned. Then one must carry the responsibility and keep alight the hope for a decade or so before it eventually flies. The type of people one works with in space must be both dreamers and strong believers; intellectually they must be outstanding. The politicians one meets must match this endeavour within their mandate. It is a big challenge to get the two on to the same wavelength but, once in a while, it works and then a good future for European space cooperation is assured.

But we in Europe are not alone. When I came into the space business we were still very much the junior partner to our American friends in NASA. NASA had helped the European space effort along - let's not forget it. All our early satellites were launched by American rockets and we learned a great deal during Spacelab development. However, it is better not to remain as the junior partner and it so happened that the relationship changed during my four years at ESA. Matters came to a head over ISPM (International Solar Polar Mission - now renamed Ulysses), the joint NASA/ESA programme in which it was planned that two satellites would pass simultaneously but in opposite directions over the poles of the Sun, exploring space well outside the ecliptic plane for the first time. Suddenly, in January 1981, NASA withdrew their satellite, an apparently crippling blow to the mission. Subsequent negotiations did not reinstate that probe but paved the way for a more respectful and, finally, cordial cooperation between the two agencies. The next major event was very positive. The first Spacelab flight on STS-9 in December 1983 succeeded beyond all expectations. The Europeans had made an important contribution to the US space transportation system - and it worked. Europeans had shown to the world that they had reached maturity in the space business.

Ariane is now a strong force among the world's launchers. I saw the first launch of an Ariane 3 in Guiana, when two European communications satellites were injected into precise transfer orbits. Both satellites, the

Facing column: despite some early setbacks, the Ariane European launcher is now established as a competitive space launcher. *ESA*





The flight of Spacelab 1 in November/December 1983 demonstrated that Europe is now capable of manned space flights. *NASA*

European ECS-2 and the French Telecom 1A, are performing perfectly in orbit. Exosat, launched last year, is the world's foremost X-ray observatory. Meteosat has become a household word, its images received by millions on television. Marecs and ECS-1 are both working well. I have seen Europe grow to maturity in space science and space technology, with the European aerospace industry and ESA working together as a team. The new technology is here and we know where and how to use it.

The Future

Naturally things do not stop now. There are new dreams and new objectives to be met if we are to maintain and further European space cooperation as a world force. A plan for the European space engagement up to the end of the century and beyond has been presented to the ESA Council and the technical and political work is in progress to have the plan endorsed during the next 15 months.

I see Europe gaining independence in space, step by step. The launcher is there and Europe's rôle in manned space flight will be consolidated. We have demonstrated our ability to develop and exploit telecommunications by satellite; further development will bring us in to a leading world position. Earth observation, the newest European discipline, is only just beginning but the omens are good. What can be done in microgravity is exciting and will be exploited.

Looking ahead, I believe that our space science programme, which has been so successful despite the limited funding available, will be granted a much-needed financial increase. In 1986 Europe will play an even more prominent rôle when the Giotto probe passes close to Comet Halley. Europe is a world leader in space science and we will continue to accelerate. It should be remembered that it is in the scientific satellite projects that Europe has been most daring in its use of technology. Through the space science programme not only scientific but technical dreams have become reality. Quality, rather than quantity, has been our password.

I have worked in the space community now for four years. I had my initial ideas and dreams when I started and now, as I leave ESA, I must confess that these have been more than rewarded by the many successful European space events of that period. I shall watch the future with keen interest in the knowledge that I helped to build it.

FROM THE SECRETARY'S DESK

Visit of JSC Director

We were delighted to welcome to HQ recently Dr. Gerry Griffin, Director of the NASA Johnson Space Center which is now primarily responsible for the fabrication of the Space Station.

Gerry returned to Houston in 1982 as Director when Kris Kraft retired. Almost immediately, his No. 1 job was to secure Space Station approval from the US Congress besides keeping an eye on the Shuttle to make sure it stayed on course - up to then it had flown only four test flights. Gerry sees his task as really trying to build up a space infrastructure. He likens the present space scene as being rather like a railway without any stations, sidings or wayside buildings i.e. consisting solely of lines from A to B.

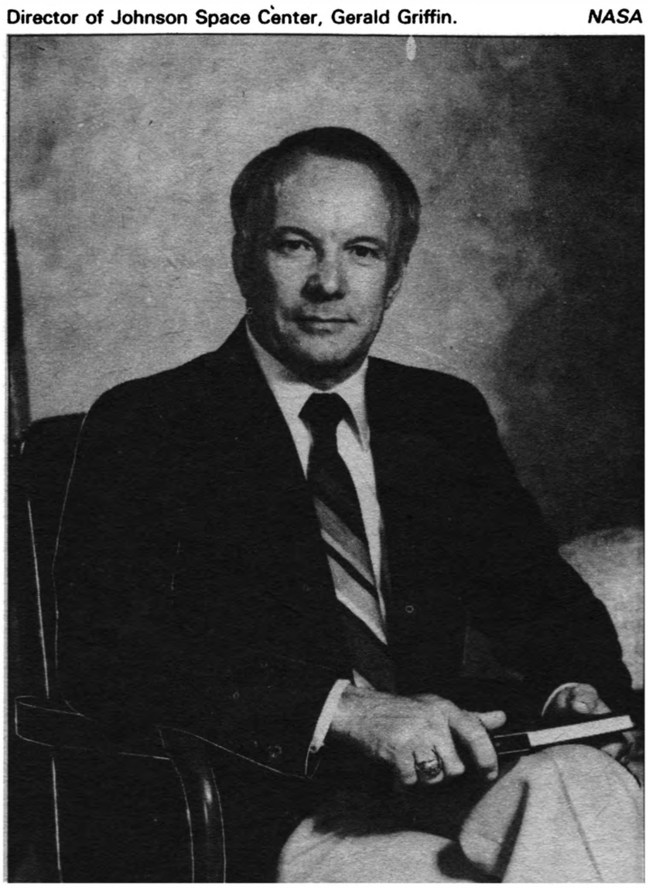
The US space station project, undoubtedly, owes its existence to President Reagan. His attitude of "It's time to have some vision and look to the future" won the day. Had he not been personally involved, the Space Station would probably still be in the administrative jungle - a lesson that could apply to this side of the Atlantic also.

Replying to the argument that funds are spent either on science or space projects i.e. they are competing, he said that NASA experience contradicted this, with science flourishing *because* of major programmes. During the Apollo development years, for example, scientific budgets increased all along the line i.e. they actually *grew* then. Many American scientists today now realise this.

Gerry grinned ruefully when he reflected on how much time and effort had been spent by the press recently discussing the Shuttle waste management system. "Here," he said, "we have this large, highly complex manoeuvrable Shuttle system, yet at a recent press conference between one and 1½ hours was spent answering questions from the media solely on the "potty." The Shuttle programme must be successful, he added, if this was the main topic! Actually, the flight of *Discovery* went so well that there probably wasn't much left to talk about. Gerry was genuinely surprised to learn how sparse had been the UK media coverage of such an incredibly sophisticated and important event and wondered if the key lay in the lack of UK space involvement.

It undoubtedly does.

Director of Johnson Space Center, Gerald Griffin. *NASA*



Welcome Visitor

We were delighted to welcome to HQ John Hodge, Deputy Director of the NASA Interim Space Station Project Office, an emigre Englishman who has made a great success abroad.

John left Vickers Armstrong at Weybridge in 1952 to go to Avro, Canada, joining NASA just as its manned programme got under way. He recalls sitting around a table, with companions, designing the Control Center-to-be at Houston. Like all good concepts, it first appeared on the back of an envelope!

NASA has been trying for 25 years to put a Space Station programme together. Now, with the aid of John's inspired team, a second giant leap for Mankind daily becomes more likely.

The World of Comets

We recently obtained a small booklet called "Tractatvs de Cometis" by D. Roccamora, published in Rome in 1670 and dealing specifically with the comet of 1664. My first instinct was to check it against the Catalogue of the Crawford Library of the Royal Observatory of Edinburgh, probably the Bible of all interested in comets. This Collection contains most of the works on comets prior to 1921 - no less than 1,261 items all told - without taking into account additional material held in pamphlet form! The earliest item listed is dated 1473, with another seventy manuscripts from the 16th century and a further 350 from the 17th century.

Surprisingly, our own modest possession wasn't listed.

Have we acquired something lacking from this world-famous collection?

Job Spec

Space Education is full of advice to those seeking space-related jobs, even up to becoming an actual astronaut. Sadly, little seems to relate to us even though we are right in the middle of the astronautical scene, as must be only too apparent from our publications and announcements.

Years ago, an employer looked for knowledge of the three R's (reading, writing and 'rithmetic) as a sound basis but the things we seek are second sight, thought transference and the ability to use a divining rod.

When it comes to education I recommend the study of navigation: This is essential if one wants to miss the multitude of traps and snares.

The acquisition of actual knowledge comes rather low. Everyone around already claims to know more than I do, whatever the subject.

Bigger and Better

I commend to all members the latest Council initiatives to secure a greatly enlarged Society membership. A total of 10,000 is not beyond our grasp. The latest offer (reproduced elsewhere in this magazine) is to ask members to publicise our special one-year introductory first-time membership for the specially-low rate of £16.

This is a real saver and one that ought to help to boost our membership substantially.

STS-9/SL1 Presentations to the Society

The Society was greatly honoured to receive the signed montage of pictures and crew patch (reproduced below) from the STS-9/Spacelab 1 crews. Astronauts Young, Shaw, Parker and Garriott signed at Houston during April-May 1984: the payload specialists added theirs subsequently *viz* Ulf Merbold signed in May and Byron Lichtenberg in June. The patch was one which actually flew on the Shuttle and circled the Earth 166 times.

The montage is particularly interesting not only because Ulf Merbold was the European Space Agency's first man in space but also because this marks the first flight of Spacelab and Europe's entry into manned space flight.

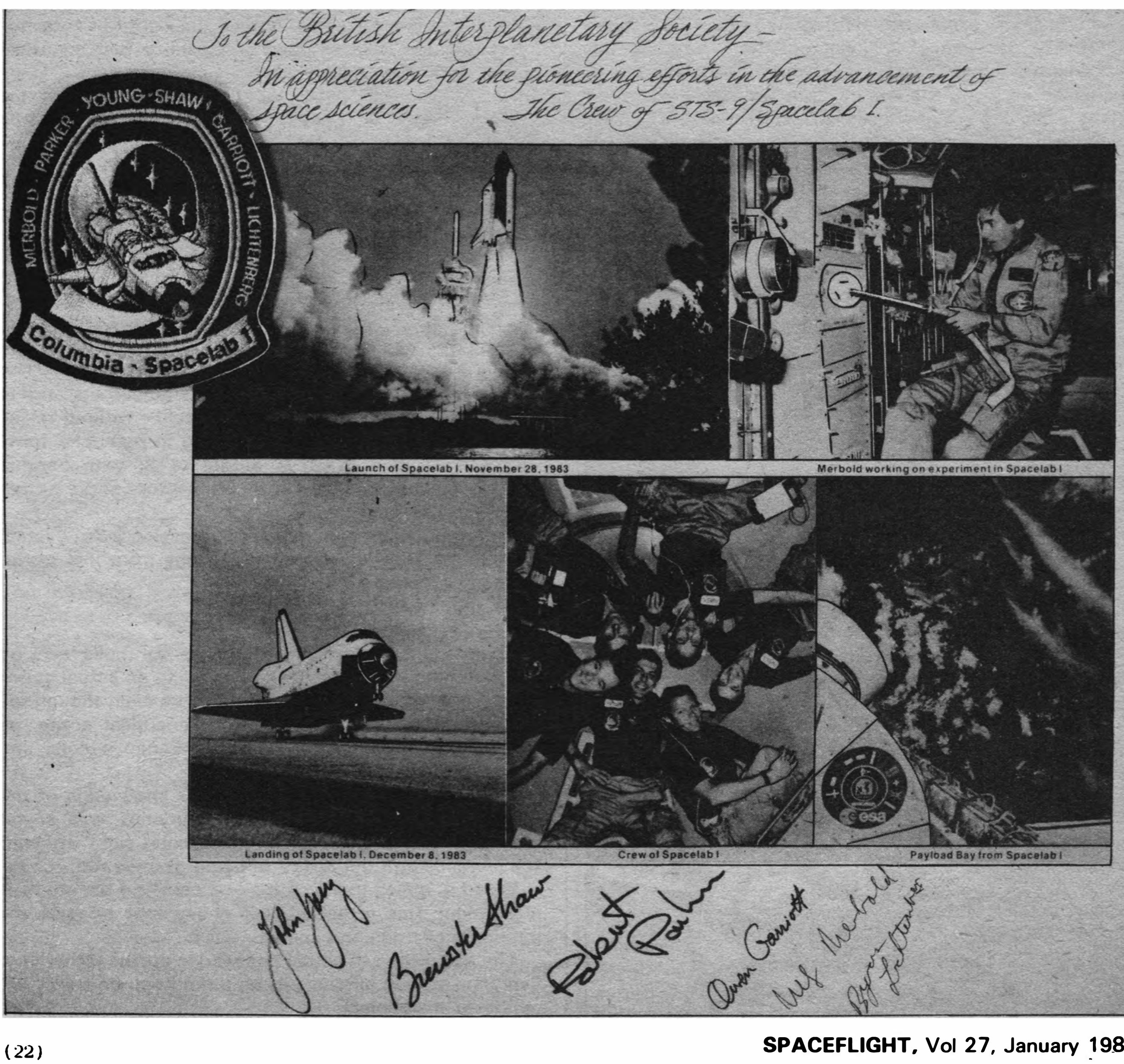
Besides demonstrating that Europe can produce first-class flightworthy hardware, Spacelab opened up completely new opportunities for performing space science in orbit in quite a different way. For example, by using the POCC and TDRS, it became possible for experimenters-on-the-ground to be part of experiments on board - *via* video and sound links and the payload specialist.

The Society is happy to record, in this way, the emergence of Spacelab as a stepping stone towards Europe's space goals.

Deeds of Covenant

I cannot urge too strongly upon those members liable to UK tax to take out a Deed of Covenant, if they havn't already done so. There is an estimated £10,000 in additional funds which the Society could secure simply by this means.

The Deed itself has only to be signed and dated and witnessed. Thereafter, it is returned to the Society for processing and the member sees no more of it. Deeds are valid for four years i.e. they represent a promise by each member to pay his subscriptions for four years though, in practice, the Inland Revenue doesn't insist on this where the Deed is not continued for some good cause e.g. falling on hard times, illness, etc. The financial impact of the Deed upon each member, most of whom join us for life, anyway, is therefore almost nil. If desired, the Deed can be continued on an annual basis after the first four years for as long as each member wishes.



THE BIS IN SPACE

By Dr. L.R. Shepherd

The rôle of the British Interplanetary Society as a promoter of space activities is as important now as ever, for there is still a great deal of work to be done in convincing the world of the value of astronautics.

Introduction

The emergence of Man from the confines of his native planet marks the beginning of a new and fundamental stage in human evolution. He has broken the bonds of gravity and ascended from the depths of the pit in which his species evolved, to a plane that has no perceptible boundary. His accessible environment is now virtually infinite in its extent and his freedom of movement is restricted only by the fetters of time, his short life and the enormous distances to be traversed.

Where destiny will take him in ths immensity of space is yet beyond his imagination but it is barely conceivable that, having made the initial ascent from the pit, he should remain forever loitering at its brink and there his destiny should end, close to the bounds of Mother Earth. On the contrary, logic dictates that, following his first leap into space, Man should be destined to explore and occupy an expanding domain within his, new, unbounded environment. However, logic does not necessarily determine the *development* of human affairs. Many factors could work to deter or limit Man's advance into space, or hinder progress to the extent that the prospects of further achievements, within the foreseeable future, might disappear.

The development of new technologies is constrained, not so much by the magnitude and complexity of the technical problems to be surmounted, however formidable, as by the difficulties of securing adequate funding and the allocation of sufficient resources to overcome them. Sadly, the wealth and resources of this planet are limited though the demands upon them grow ever, greater. Space technology has to compete with countless other demands for the resources it needs for advancement. Considerable effort is required on the part of those who endorse the human venture into space if it is to receive the priority and financial support adequate to ensure its continuation.

This is why, in a generally unfavourable economic environment, the case for the expenditure of money and resources on space projects has to be argued with great conviction against many other demands of seemingly more immediate concern. Besides that, except where established applications (such as communications satellites) are involved, the extremely high level of funding required for space projects goes beyond that available from normal commercial sources, particularly in view of the obvious absence of early financial benefits. Consequently, governmental investment, on a national or international basis, is essential. Sponsorship of space technology by governments, in the initial stages, has been obtained largely by virtue of military considerations or through the desire to enhance national pride and prestige. More recently, commercial incentives have come into the picture and there has been a limited governmental recognition that the pursuit of pure scientific research in space must also merit some support.

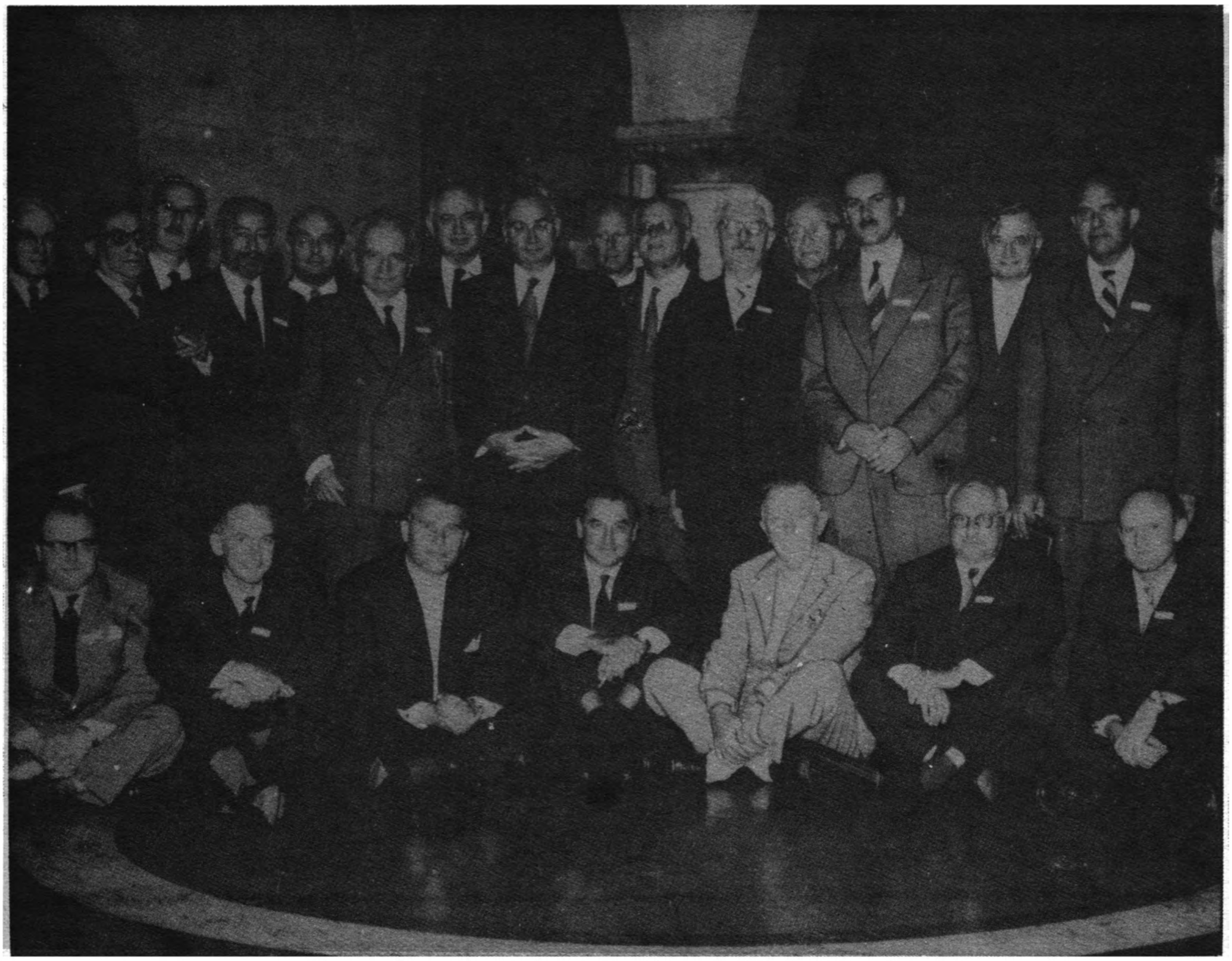
The Future and the BIS

If Man is to proceed to the next stages in his conquest of space, then there needs to be a continuing acceptance of the importance of the purely scientific motive and, above all, a far-sighted realisation that new and advanced developments in space technology, going beyond the prospects of immediate commercial benefit, must receive a reasonable measure of support. This clearly indicates that the main rôle of the astronautical societies is to engender, in the minds of the public and governments, a recognition of the fundamental significance of space flight and an acceptance of the need to fund long term space technology adequately.

Valentina Tereshkova, the first woman in space, proudly displays the BIS medal presented to her in 1964 The Society also recognised the supreme achievement of Apollo 11 and presented each of the three astronauts — Neil Armstrong, Edwin Aldrin and Michael Collins — with a gold medal.

Most nations justify military expenditures, which often go far beyond their economic capacities, on the grounds of state security. It may be argued with even greater force that the funding of non-military long-range developments in space might prove vital to survival. Such arguments rest upon the facts that the opening of the space frontier should enormously enhance the resources available to Man and that the dispersal of humankind over many worlds will provide a safeguard against both natural and self-inflicted disasters. Astronautical societies have the responsibility to argue such fundamental points to the utmost of their ability.

From the outset, the British Interplanetary Society has seen its rôle in this light. Founded in 1933, when all aspects of space flight were treated with derision by the great majority of the established scientific community, the designation "Interplanetary" left no element of doubt



The BIS was instrumental in the formation of the International Astronautical Federation. Pictured here are a few delegates of the Stockholm Congress in 1960. BIS Fellow Hermann Oberth, who celebrated his 90th birthday last June, is standing sixth from the right. The author is seated second from the left, to the right of the late BIS Fellow Wernher von Braun.

as to its ultimate aims and convictions. Many arguments were put forward during its early years to set the Society's sights lower, reflected by a more mundane name. These were all rejected. Today, after men have set foot on the Moon and numerous spectacular interplanetary excursions have been made with robot spacecraft, the name is now far from fanciful. Even so, it still has to be interpreted as meaning that our Society is not one with limited horizons.

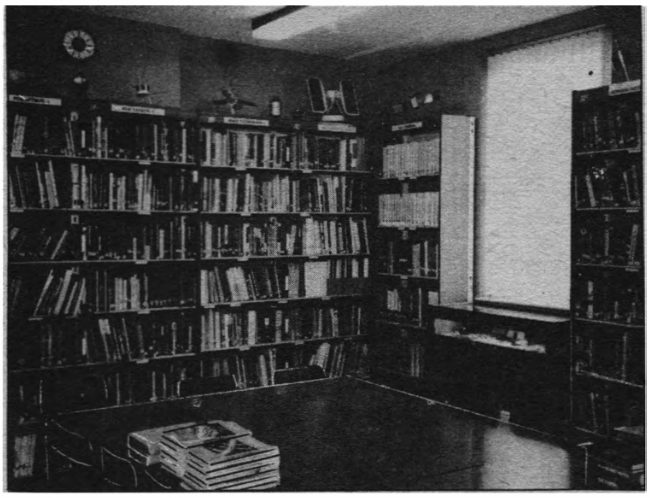
A principal function of any society is to provide the medium for the dissemination of new information and knowledge in its specified areas of interest. It also should be concerned with the *propagation* of knowledge, not just in a specialised form for the serious student, but in a more popular form for the benefit of others. These responsibilities are normally discharged through publications and the organisation of lecture programmes, symposia and conferences. Those societies that are politically inclined may also try to promote their fields of activity by appeals for sponsorship to governments and other potential sources of support.

Over all these broad areas of astronautics, the British Interplanetary Society has been active in every respect. It assigns the highest priority to regular publications in both popular and specialised forms. It has matched this by attention to the organisation of meetings ranging from single lectures to large conferences and it has always seen, as one of its main tasks, the need to make appropriate representations to all areas of Government, for the support of space technology.

On the matter of publications our Society, *within three months of its foundation*, produced the first issue of its Journal (*JBIS*), dated January 1934. It was no more than a pamphlet of six pages, *albeit* properly printed on good quality paper. During the succeeding six years to September 1939, when all activities of the BIS were suspended for the duration of hostilities, 12 issues of the Journal were published, at irregular intervals but expanded to 28 pages - small format (140 mm x 220 mm). Now, 50 years later, it is a monthly magazine of, typically, 48 (A4) pages.

Over its first 20 years, *JBIS* carried a mixture of papers, some of a technical character and others of purely popular appeal. In the mid-1950s however, with governments in both the USA and USSR proclaiming their intentions to build and launch orbital space vehicles, there was a clear need to publish more information for the benefit of the general public. The BIS considered that, for its part, it could not meet the new situation with a single publication so a popular style magazine, *Spaceflight*, was introduced to serve the growing public interest, leaving the Journal to meet the needs of those with a serious professional concern in astronautics. The first issue of *Spaceflight* appeared in October, 1956, as a quarterly publication. After four years it was published bimonthly and, from 1966, it has seen 10 issues a year in the same A4 format as the Journal.

In strict terms, the Journal is not a single publication but is subdivided into a number of distinct series, each



The Society's Library.

devoted to a particular area of interest. These areas range from the immediate applications of space technology to the very long term possibilities that are covered in the Interstellar Studies series. They reflect the concern of the Society with the broad implications of astronautics rather than a narrow concentration on matters of immediate practical significance.

From time to time the BIS has published material in the form of single issues or books and, recently, introduced another magazine *Space Education.*

In the information field, the Society has not confined its activities to printed publications, but, from the earliest days, has organised lectures, not only for its own members, but also for other bodies including schools, clubs and professional societies. Increasingly, over the past 30 years, these meetings have included symposia and exhibitions, often extending over more than one day. In many cases these meetings have been organised in collaboration with other national societies or on an international basis with its contemporary astronautical institutions overseas. In this last connection, particular reference should be made to the stress placed by the BIS on the desirability of organising astronautical ventures on an international basis and its consequent interest in promoting cooperation between the many national space societies that now exist around the world. The BIS has played an important role in securing such collaboration.

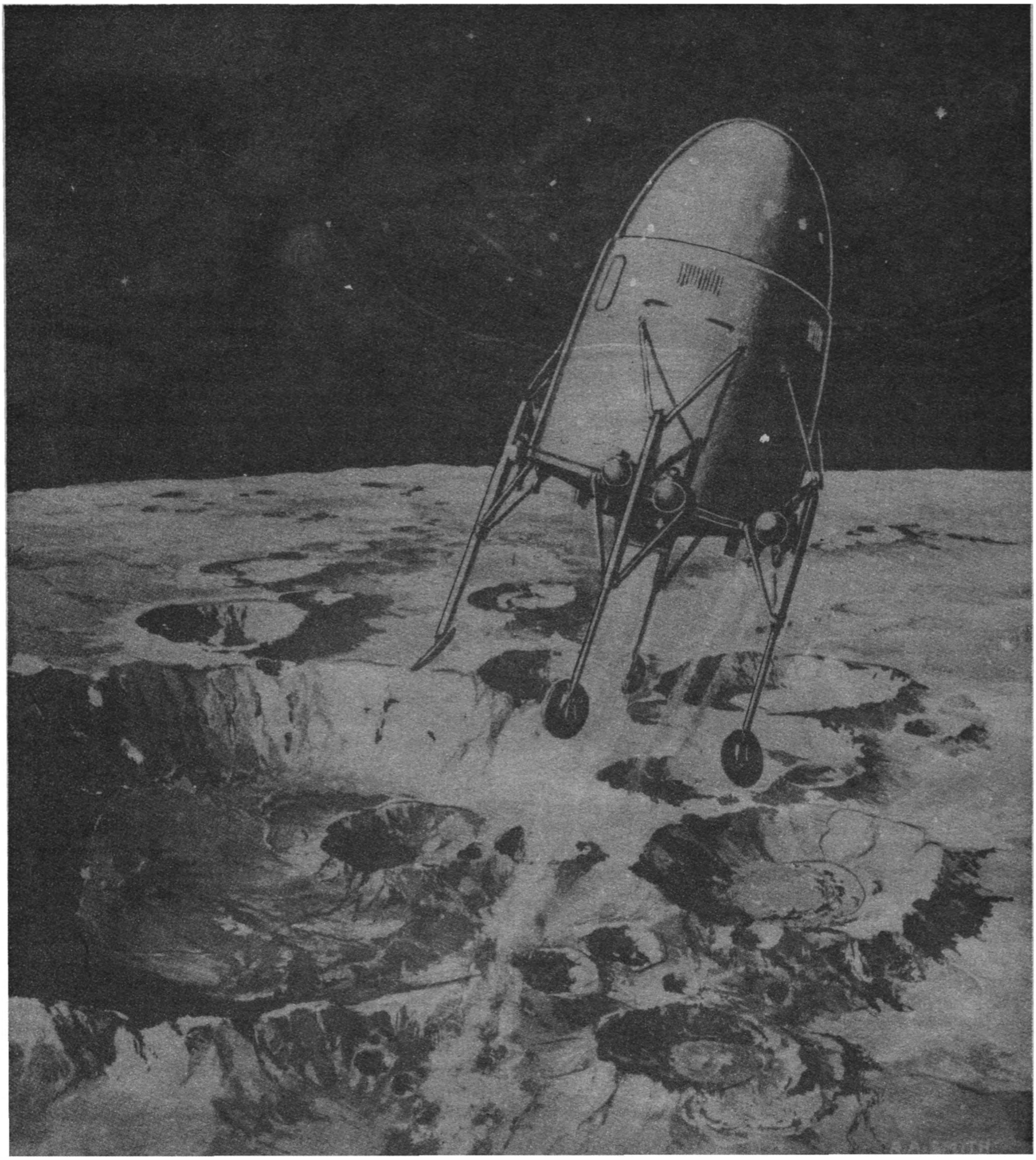
The outstanding example of the part played by the BIS in promoting cooperation between the world's space societies was its significant role in the foundation of the International Astronautical Federation. In 1949, the Gesellschaft fur Weltraumforshung, based in Stuttgart, suggested that the BIS should organise, in London, a meeting of the various national astronautical and rocket societies in order to explore avenues of collaboration leading to the establishment of some form of association between them. The BIS responded enthusiastically and proposed that the London conference should be held in 1951. In the event, an earlier meeting was arranged in Paris by the Groupement Astronautique Francais, at the end of September 1950, between respresentatives of eight societies, from Argentina, Austria, Britain, Denmark, France, the Federal Republic of Germany, Spain and Sweden, where the conclusion was reached that some form of association should be created and that its inauguration should take place at the larger London meeting in the following year. The BIS was charged with the responsibility for organising the London conference and for coordinating proposals specifying the form and constitution of the intended association, in correspondence with the other founding bodies. This task was duly discharged and at the London meeting, which was held at Caxton Hall, Westminster, during the first week in September 1951, the International Astronautical Federation was brought into being, the founding societies consisting of those from the countries that had been represented at Paris, joined in London by astronautical societies from the Netherlands, Italy, Switzerland and the USA. One of the principal functions of the Federation was to be the holding of an annual International Astronautical Congress and it was agreed that the preliminary meeting in Paris and the London conference should respectively, be, designated as the First and Second of these Congresses.

The BIS rôle as a founder member of the IAF did not end there. In September 1959 it played host to the Tenth International Astronautical Congress, at Church House, Westminster, on which occasion the sister organisations of the IAF; the International Academy of Astronautics and the International Institute of Space Law were founded. It might be regarded as fitting that these three world-embracing astronautical institutions should have been born within the precincts of the "Mother of Parliaments."

In a narrower international sphere, the BIS joined with its sister societies in France, West Germany and Italy and with Eurospace, the industrial European space forum, to establish the European Space Symposium. The first of these Symposia was organised by the BIS in London in 1961 and was devoted to papers assessing the problems of re-usable launch vehicles. Later, the American Astronautical Society joined the group to broaden the scope of the Symposia.

The activities of the BIS have extended beyond the more orthodox pursuits outlined above. From its foundation, it was the intention that the Society should make original contributions to the technology of space flight. In the pre-war years most of the contemporary astronautical societies shared this purpose and generally attempted to satisfy their aspirations by conducting primitive experimental programmes in rocket propulsion. The founders of the BIS examined this option but considered it impracticable and concluded that the creative urges of the Society ought to be fulfilled in some other manner. They decided on a course that was both realisable and potentially useful *viz* to conduct technical assessments that would identify the feasibility of space missions and, perhaps, provide useful guidelines to future technologists with the material resources to carry them through. In modern technology, of course, all major projects are preceeded by years of "paper studies" with precisely this purpose. They can vary in scope from long range speculative investigations, far ahead of likely application, to the large and expensive assessments and design studies that immediately preceed the actual commitment to a project. Activities in the latter category require the resources of research and development centres but the more conjectural preliminary assessments fall within the capacities of small groups and even individuals who have little more than their enthusiasm; adequate professional knowledge; access to the technical information involved and, today inevitably, their own microcomputers and electronic calculators.

In those early days the Society, therefore, set up its first technical committee to organise groups to conduct assessment studies of a conjectural, but nevertheless serious, nature. At that time, the electronic aids to computing had yet to be developed and background information in space technology was virtually non-existent, but there was no lack of enthusiasm or volunteers ready to devote their leisure hours to this activity. The first study thus conducted, in the pre-war era, was an assessment of a manned lunar flight. In the event, this was removed



The BIS paved the way to the Moon in its lunar lander studies of the 1930's and 1940's. The full story is told in the Society's book "High Road to the Moon", available at £6, post free, from the Society.

by a mere 30 years from the actual realisation, but in terms of technology it was an age removed from possible achievement. It may be said of this study that, while in terms of propulsion and launch vehicle engineering it was far from the mark, it depicted with remarkable accuracy the techniques of landing and take-off from an airless body like our Moon. In fact, the lunar landing vehicle of the BIS study, which was illustrated in *JBIS* soon after the war, bears an uncanny resemblance to the Apollo Lunar Module.

When the Society was reformed in 1945, it resumed activities in the sphere of technical assessment and such studies have now become a tradition of the Society. This is why a technical committee structure has been maintained, to solicit or encourage studies by individuals or groups, with much of the space in *JBIS* devoted to the resulting reports. A result of this policy has been that the *JBIS* has become a medium of international repute for the publication of serious speculative investigations in the forward areas of astronautics. These have come increasingly from authors outside the Society's own study groups, often describing work conducted in governmental and other astronautical research centres.

Technical assessments may be of a short, medium or long range character, depending on the state of the technology demanded for their realisation. The first category would involve projects that can be achieved by established technology. Since they are based on known

engineering principles, these assessments may be made in sufficient detail to enable reasonable cost estimates to be included. Indeed, one reason for carrying out an assessment might be to demonstrate that the foreseeable benefits from a project would amply justify its cost. Medium range assessments, on the other hand, look ahead towards projects dependent upon technology yet to be demonstrated, but nevertheless describable in meaningful terms. Cost evaluations, in such cases, may not be of much significance for the purpose of the assessments would not be that of securing immediate project funding, but, rather, to point the way ahead and justify investment in the development of the basic engineering involved. Finally there are the long range projects dependent upon technologies still beyond Man's scientific capabilities but conforming, nevertheless, to established scientific principles, so that the assessments are raised above the fictional level. The object in carrying out assessments in this category are largely philosophical but very useful in exploring the far frontiers of Man's environment and understanding the problems that have to be confronted in extending them.

Of course, there are no clear demarcations between the categories of assessments described. Broadly speaking, the manned space stations now projected come into the short range class, as would the next stage of lunar exploration by Man and the programme of unmanned planetary missions. On the other hand, manned expeditions to the planets and the establishment of bases on the Moon and Mars must be assigned to the medium range category for, although their accomplishment can be described in terms of existing basic technology, they lie at present outside the scope of practicable engineering. Interstellar exploration, in the full sense of its meaning, falls far into the long range category.

The astronautical interests of the BIS are wide-ranging and comprehensive. Its publications endeavour to cover every aspect of the subject, from the early history to the far frontiers of interstellar flight. It does not seem appropriate, however, for an astronautical society to try to conduct technical assessments of a short-term nature. With space already a commercial area, such studies are of little serious value unless they made in considerable detail, thus requiring a scale of effort available only in well-funded centres. In its internal assessment activities, therefore, the Society is concerned more properly with medium range developments that do not yet demand detailed analysis and, beyond these, with the long term possibilities which are of fundamental signficiance. As far as the short term is concerned, the rôle of the Society is more that of a reporter, educator and supporter. Such is its attitude, for example, with respect to the now imminent development of manned space stations.

The BIS was founded with the principal objective of promoting the development of space flight with special interest, of course, in getting such work underway in the UK. This attention to the political side of astronautics has been maintained and widened through its association with contemporary societies in other countries. The present surge of activity in space is heavily concentrated in the hands of the USA and USSR which, together, constitute only 11% of the human race so there is a need for a much greater involvement by the other 89%, not only by the industrially advanced countries of Europe, Japan and Oceania, but also by the poorer countries that make up three quarters of the world's population. Because of its geographical location, the BIS, naturally, is intimately concerned with European countries: Simply expressed, it sees the need for a programme in the ESA countries commensurate with that of NASA in terms of the proportion of the Gross Domestic Products involved (0.5% in USA, but only 0.05% in ESA countries). Within ESA, it would wish to see the UK contribution raised to match that of its major partners, instead of falling far short as it presently does.

BIS President A. T. Lawton displays the congratulatory plaque received from the International Academy of Astronautics to mark the Society's 50th Anniversary in October 1983. Behind is a further plaque, presented by NASA.

Nearly all the activities of the Society, (publications, lecture programmes, symposia, exhibitions etc) contribute to this political purpose and in the long run these day-to-day pursuits may prove to be the most effective ways of bringing the importance of investment in space to the notice of government and the public. In addition, the BIS has taken actions of a more specific character in the form of letters and memoranda to the government of the day. The first of these was a document, submitted to the Macmillan Government in 1960, which proposed that the Blue Streak and Black Knight liquid propellant rockets (developed for an abandoned military purpose) should be adapted as a satellite launch vehicle. The document also recommended, among other things, that studies should be conducted into the technical feasiblity and commercial significance of communications satellites and that research should be done on winged re-entry vehicles. In the event, Blue Streak was embodied into the ELDO Europa launch vehicle and Black Knight became the base stage of the Black Arrow launcher, which was abandoned after placing one small satellite in orbit, a typical fate for successful British projects! Communications satellites are now a major part of the UK space-related programme, but the other recommendations of the Society, in this memorandum produced little action.

Subsequent memoranda to government placed the main emphasis on the need for a Western European space authority which would be responsible for the ongoing developing of launch vehicles and other aspects of space activity, including manned space flight. Such a recommendation to the Wilson Government in 1965 met with no positive response but a second, along similar lines, to the Heath Government in 1972 served to reinforce a growing feeling in official circles that a unified Western European space programme was desirable and, within two years, the European Space Agency was set up. It is the purpose of the Society to generate such official and public receptiveness through its day-to-day activities.

HALLEY'S RETURN

Many members have asked us for the important dates and events in the 1985/86 apparition of Halley's comet. Dr. John Davies of the Space Science Dept. of the University of Birmingham has compiled the table below to provide a key list of the highlights.

1984
Mid-Dec: Launch of two Soviet Vega probes to Halley *via* Venus (arrive Venus June 1985).

1985
Jan: Launch of MS-T5 (Japanese Halley mission pathfinder).
Jan: Halley crosses Jupiter's orbit.

May 5: Eta Aquarids meteor shower at maximum; best seen from southern hemisphere; Halley debris.

Jul 10: Giotto (ESA Halley probe) launch from Korou, South America, by Ariane.

Aug: Halley might be visible to large amateur telescopes from this month onwards.
Aug 14: Launch of Planet A (Japanese Halley probe).

Sep 5: Giacobini-Zinner perihelion Sept 5.26, 1.03 AU from Sun, 0.47 AU from Earth.
Sep 11: ICE spacecraft (US) encounters comet Giacobini-Zinner at relative velocity of 20.7 km/sec.

Oct 10: Draconid meteors at maximum.
Oct 20/1: Orionid meteors at maximum.
Oct 31: Sun/ICE/Halley in alignment, detect response to solar wind.

Nov 28: Halley crosses Mars' orbit.

Dec: Halley visible to naked eye from Britain.

1986
End Jan: Halley lost in evening twilight.

Feb 9: Halley perihelion (not visible to naked eye).
End Feb: Halley reappears in morning sky, too far south to be seen from Britain.

Mar 8*: Japanese Planet A spacecraft flys past Halley.
Mar 9*: Soviet VEGA 1 flypast of Halley.
Mar 13/14: Giotto intercepts Halley about midnight GMT.
Mar*: Soviet VEGA 2 flypast of Halley.
Mar 31: Sun/ICE/Halley in alignment, detect response to solar wind.

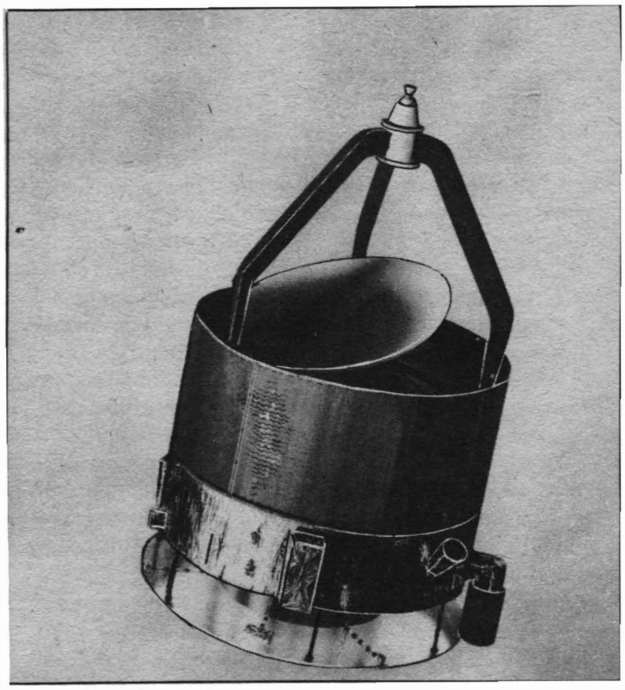
Apr: Most spectacular views of comet (from southern hemisphere).
Apr 11: Halley at closest to Earth, 0.42 AU.
Apr 23: Halley crosses Mars orbit outbound.

May 5: Eta Aquarid meteors at maximum, Halley debris.
Mid May: Halley fades below naked eye visibility.

Jul 1: Halley now faded to 10th magnitude, good amateur telescope needed to see comet.

Orbital Information (1986 return)
Period: 76 years.
Aphelion: 35.29 AU = 4831 million km.
Perihelion: 0.587 AU = 87.82 million km.
Perhelion date: Feb 9.44 1986.

* Dates of spacecraft encounters may change slightly.



Giotto nears the nucleus. *Bae*

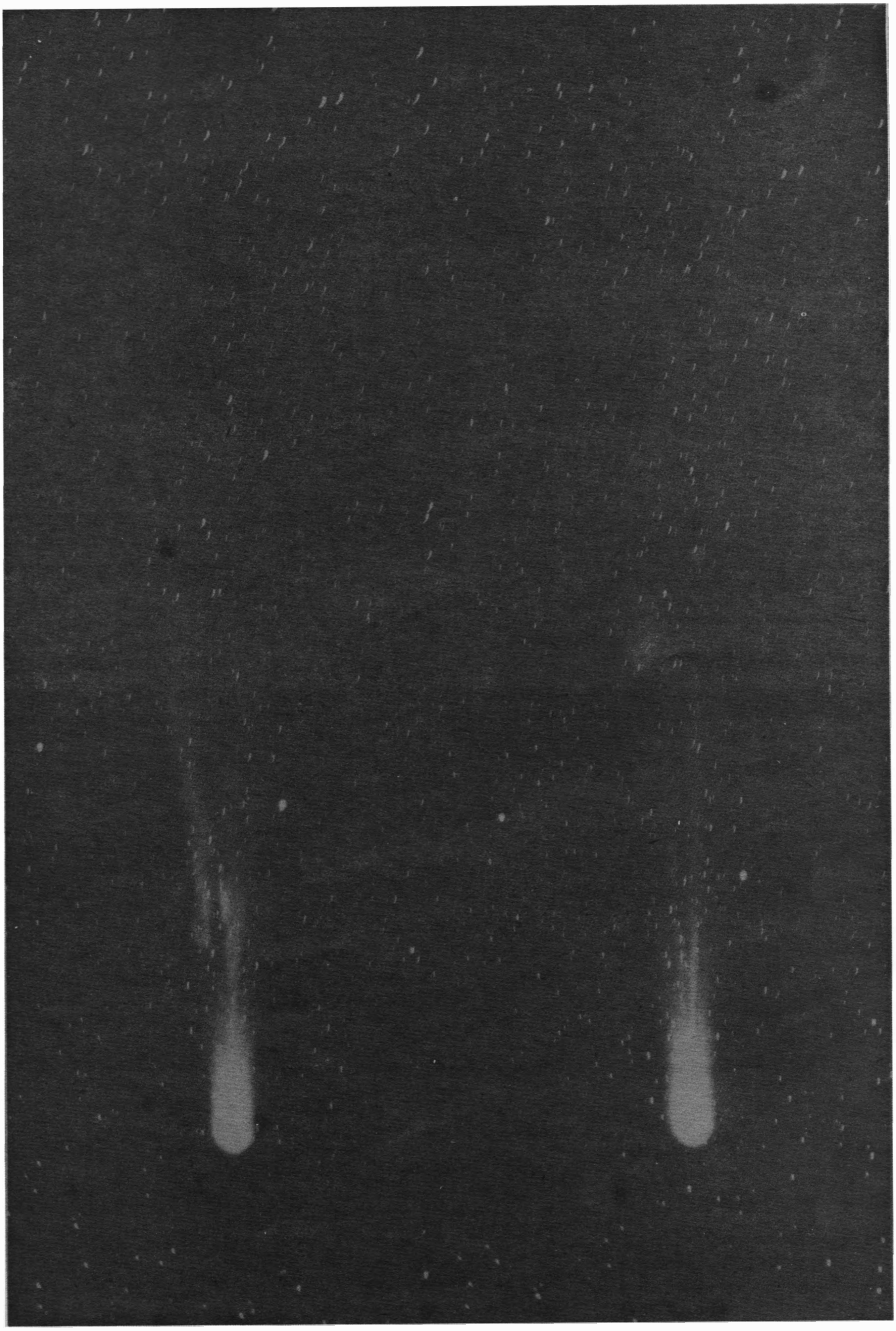
Closest approach to Earth: Apr 11 1986 Distance 0.42 AU = 62.83 million km.
Inclination of orbit: 162.24° (Retrograde Orbit).
Heliocentric velocity at Aphelion: 0.91 km/s.
Heliocentric velocity at Perihelion: 54.55 km/s.

Physical Information
Estimated diameter of nucleus: 5 km.
Estimated density of nucleus: 1 gm/cc.
Estimated rotation rate: about 10 hours.

Historical Information
240BC First recorded observations (by Chinese astronomers).
837AD Closest recorded approach to Earth, 5.99 million km (April 11).
1066 Seen by Harold before battle of Hastings, incorporated into Bayeux tapestry.
1301 Seen by Giotto de Bondone, included in his work "The Adoration of the Magi."
1682 Seen (not discovered) by Halley.
1705 Halley predicts return of comet in 1758.
1742 Halley dies, aged 86.
1758 Comet rediscovered by Johann Palitzsch on Dec 25th.
1835 Second predicted return, observed extensively.
1910 Third predicted return, first photographs of Halley's comet taken.
1982 Recovered at Mt Palomar Oct 16 at magnitude 24.2.

Glossary
Aphelion: Furthest point of orbit from Sun.
AU: Astronomical Unit = 150 million km.
ESA: European Space Agency.
ICE: International Comet Explorer spacecraft (formerly ISEE-3).
Perihelion: Closest point of orbit to Sun.

Facing page: two images of Halley's comet from the 1910 apparition. *Lick Observatory*



COMMERCIALISING SPACE

Dr. David Stephenson

Space technology has progressed to the point where it will soon be possible to use space vehicles to advertise commercial products to millions on Earth. Here the author expresses his personal conception of one way in which this could occur.

Introduction

As part of the global image management industry, advertising is one of the world's most potent economic and social forces. One global fast food chain spends over $250 M per annum on advertising; in Britain 0.3% of the G.N.P. is spent on TV advertising.

Commercial inserts within audience-attracting TV programmes are the most powerful tools available to the image manager today. But, by the end of this century, the TV audience will have been severely fragmented by advances in video recording, cable and satellite broadcasting and interactive video systems.

The night sky is by far the most boring form of entertainment available today. The rare occasions when this tedium is relieved (for example, by the passage of a comet) generates a surge of public interest that demonstrates clearly the communications potential.

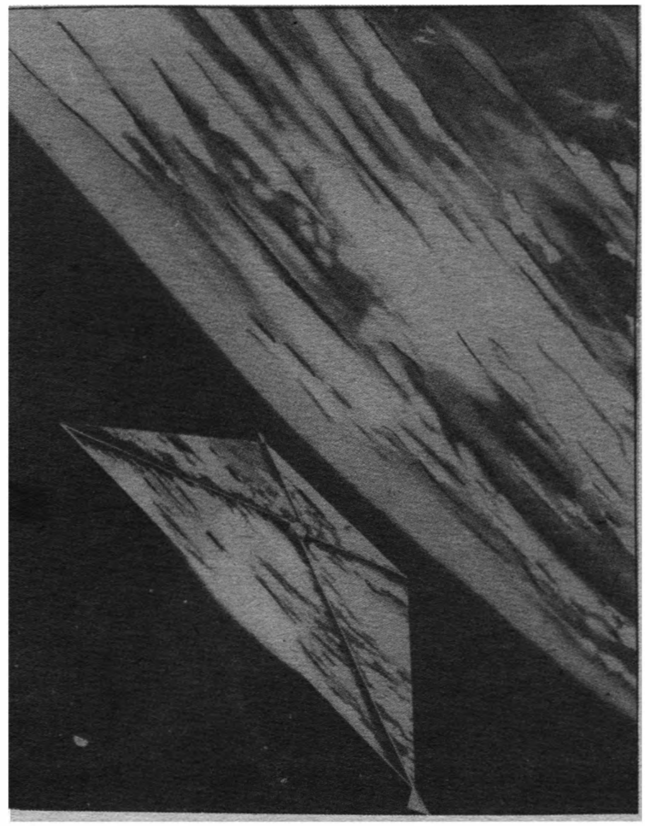
One of the unwritten rules of image management is that presentations should not conflict with the expectations of the target population, but rather should enhance and expand those expectations (to the benefit of a client). Space technologists can now seize the opportunity offered by the fragmenting TV audience and, by the end of the century, offer a service that creates flexible format, artificial constellations of bright star-like objects in the night skies of the world's cities.

System Definition

What the image management industry will probably expect from a space display system are artifical constellations in the form of logos and short brand-names bright enough to over-ride modern urban lighting over the cities and resort areas of the world. These constellations of up to 50 'stars' will have to be available for at least an hour during the late night shopping hours between 6 and 10 pm local time but, within that time, can be re-targeted several times to avoid adverse weather and to adjust to local variations in commercial activity. Although the message will not change during the display period it must be flexible to suit the requirements of many sponsors and should move to circumvent the obscuring effects of buildings and landscape. Political licencing and line-of-sight effects demand that the illuminated area on the ground will have to be strictly defined, and the display modules or artificial stars must not be so bright as to risk injury to the eyes of people in rural areas.

Lights in the Sky

Ehricke [1,2] has published extensively on using large plane mirrors to beam light and power from orbit. A small plane mirror reflecting the Sun's rays from space appears as a point source of light with a beam divergence equal to the apparent diameter of the Sun (0.00931 radians at the orbit of the Earth). Thus the minimum linear dimension of the illuminated area on the ground is 0.93% of the orbital altitude. Thus a plane mirror in orbit fulfills two of the requirements of space displays: a well defined target area and, since the light is not reflected over a wide angle, the intensity inside that area is high.

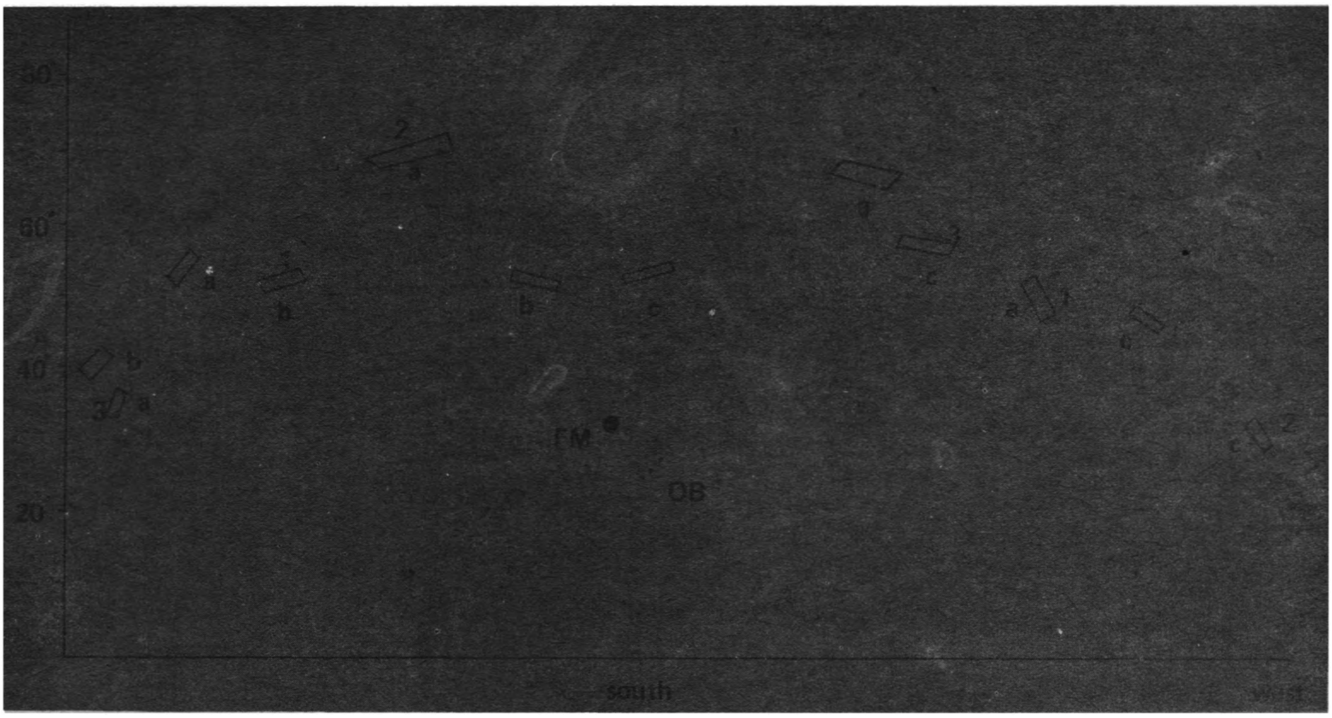


Mirrors similar to this solar sail concept of the World Space Foundation could be used to reflect sunlight to Earth. *WSF*

The concept of orbital mirrors has been promoted to aid the development of the less developed countries that certainly do not have the resources to support major space activities. If the mirrors displayed commercial logos for multi-national corporations then the services of the mirrors would, like those of American commercial TV, be available at no cost to the recipient. The less developed countries with their dark night skies and largely illiterate (i.e. symbol-orientated) populations, enhanced by free-spending tourists, must be a major target. During the development and deployment phases the response of the developed economies is going to be crucial.

In practice, an imperfect mirror away from the local zenith creates an illuminated ellipse surrounded by a halo of scattered light. But, even though the incident brightness would be reduced, because the human eye responds logarithmically a small mirror would still appear as a very bright star-like object in almost any part of the night sky of the target area.

The major markets of the world are between 22° and 55° N latitude and separated by 120° of longitude. If reflecting satellites presented displays during only one sector of an orbit then, from an eight hour orbit, they could be aimed at all market zones in sequence. For example, a display over Las Vegas would be seen eight hours later from a city in South Korea. This orbital period would optimise the use of a limited life-span capital investment and would attract clients with world-wide interests and identities. An eight hour circular orbit implies an altitude of 13,900 km and a minimum target zone dimension of 130 km. This closely matches the area of major conurbations and their dormatory suburbs, but is small enough to limit the effects on the sensitive and



Space display seen from Los Angeles at 34° N, 118° W. Orbit: 8 hour circular, median inclination 22°. Display Format· inclination ±0 5°, 3° sector. Numbers are times in hours from equator crossing at 18.00 hr LA time: a. Optimum Orbit, node above 14.00 hr local time; b. Non-optimum, −45° from optimum, node above 17.00 hr local time; c. Non-optimum, +45° from optimum, node above 11.00 hr local time. Orion's Belt and Full Moon shown to same scale.

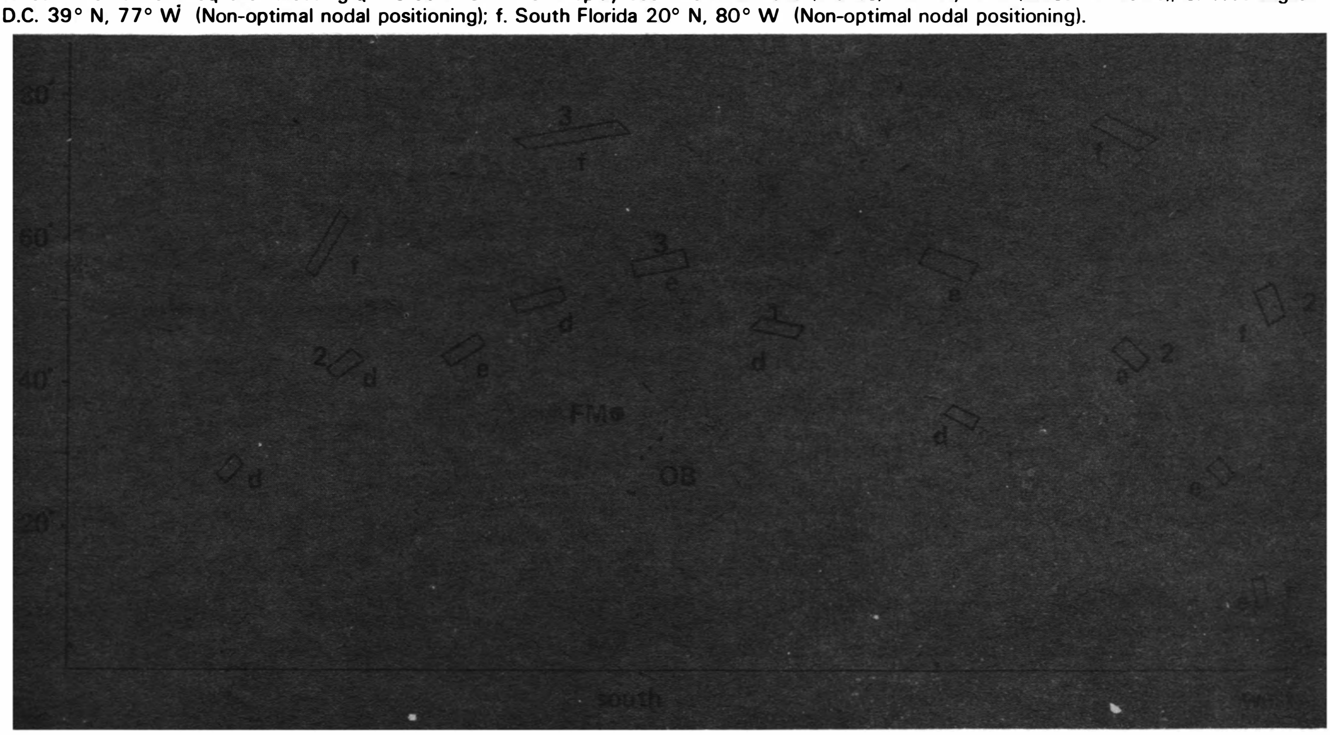
politically effective pseudo-rural halo of commuting professionals.

At 13,900 km altitude a 400 m^2 mirror seen overhead from the equator at 18.00 hours local time would appear like a star with a magnitude of −6.2; that is two magnitudes brighter than Venus at its brightest. Even when only 20° from a setting Sun the mirror would be as bright as Jupiter. A modern commercial logo would demand a constellation of up to 50 stars giving a total display brightness equal to the full Moon.

The formation for a two dimensional display will have mirrors distributed along a limited sector of a family of eight hour orbits with slightly differing inclinations. At the nodes the formation would briefly form a line, before opening out over two hours and then collapsing and inverting after the next node.

Launched from Cape Canaveral, the Space Shuttle enters an orbit with an inclination of 28.5° that is almost ideal for displays to the northern hemisphere. The prime market for space-based advertising is the 'Sunbelt States' of the south western USA. This is an area with a booming high technology-based economy, blessed with some of

Space display seen from other targets. Orbit: Optimum orbit for viewing from LA. Display Format: inclination ±0.5°, 3° sector Numbers are times in hours from equator crossing at 18.00 hr LA time. Display seen from: d. Paris (France) 49° N, 2° E (times - 8 hours); e. Washington D.C. 39° N, 77° W (Non-optimal nodal positioning); f. South Florida 20° N, 80° W (Non-optimal nodal positioning).



the clearest skies in the world and having a long tradition of untrammelled free market economic activity. Therefore an orbital inclination of 22° was used when calculating the examples shown in the diagrams to prevent the displays approaching the zenith when viewed from this area. The rectangular format with an inclination spread of ±0.5° and distributed along a 3° orbital sector shows how the display would appear from various major targets around the world. Individual display modules could be positioned freely within the display structure, so presenting a Latin letter, would need 10 modules or less. Showing the display during peak viewing times is equivalent to an ascending node above 14.00 hours local time, but two examples of non-optimal node positioning are also presented.

Despite the distortions introduced by the linear-linear scales of the figures it is apparent that up to two hours of display time would be available on each orbit. To show the impressive potential of this space technology the full Moon and Orion's Belt are included on the same scale. Line of sight distortions will occur as the modules move around their orbits but the effects are similar to those seen when driving past a conventional billboard.

Spacecraft Characteristics

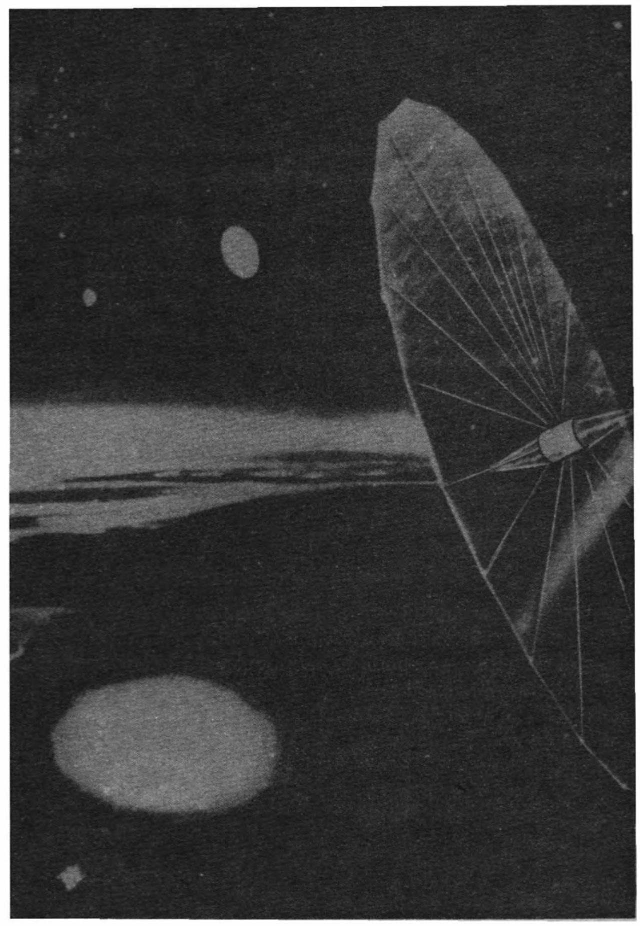
The main element will be a deployable mirror with an area of over 400 m², which may resemble the solar sailing craft shown on the front cover of the September/October 1983 issue of *Spaceflight*. Designs like this suggest that a display module should have an in-orbit mass of about 200 kg. The displays will demand a pointing accuracy of 2′ while tracking at 22′ per minute for a precision of 10 km on the ground. Morris [3] has reported that handling clusters of communications satellites has already been investigated and this work may be invaluable for the operators of space displays.

During the six hours when displays are not possible internal computers will have to perform fine manoeuvres to correct for drifts between the modules. Every few days the complete formation will have to be changed to suit the needs of many sponsors. This will be a complex procedure and considerable effort will be needed to optimise the algorithms and spacecraft systems that control the manoeuvring. Finally, every month, the complete display will have to move its nodes to compensate for the 1.2° sidereal motion of the Sun.

Some form of low-thrust high-efficiency propulsion system would seem to be most suited to the requirements of this mission. Solar sailing will be unavoidable, but probably will not be adequate for all purposes. Ion and electro-thermal motors could provide the required thrusts, but need substantial areas of solar cells to generate their electrical power. A practical design would probably be a hybrid that used solar radiation pressure for angular momentum budgeting and fine station keeping, while an electrical thruster would change formation and node position. This latter could also be used to insert the module into the eight hour orbit from the low Earth orbit reached by the Shuttle.

Costs

The proposed service would be unique and can only be compared with broadcast advertising. Thirty seconds at weekends on LBC (a local London radio station) costs £3000 and local urban TV commercials cost over $10,000 per minute. Since a space display would have to show the same logo to markets around the world for at least a day, a minimum daily contract of $100,000 would seem to be a target that would attract interest from potential sponsors.



Mirrors in orbit could be used to provide illumination for cities at night - especially valuable during the winter. *NASA*

An estimate of the operating costs of a 25 star display would be (in millions of dollars):

STS launch: (25 x 400 kg)	23.5
25 Mass Produced Display Modules	200.
5 years' operations	50.
	273.5

Continuous operation for six hours per day for five years	657,000 mins.
Less 20% maintenance	525,600 mins.

Provided that alternate targets are available to avoid adverse weather this gives a daily running cost of $190,000. Development costs and profit implies a final cost to the customer of $400,000 a day. This is currently too high, but not outrageously so. Launch and equipment costs are coming down and advertising budgets are increasing, so sometime around the end of the century 'spacevertising' should become a commercially viable proposition.

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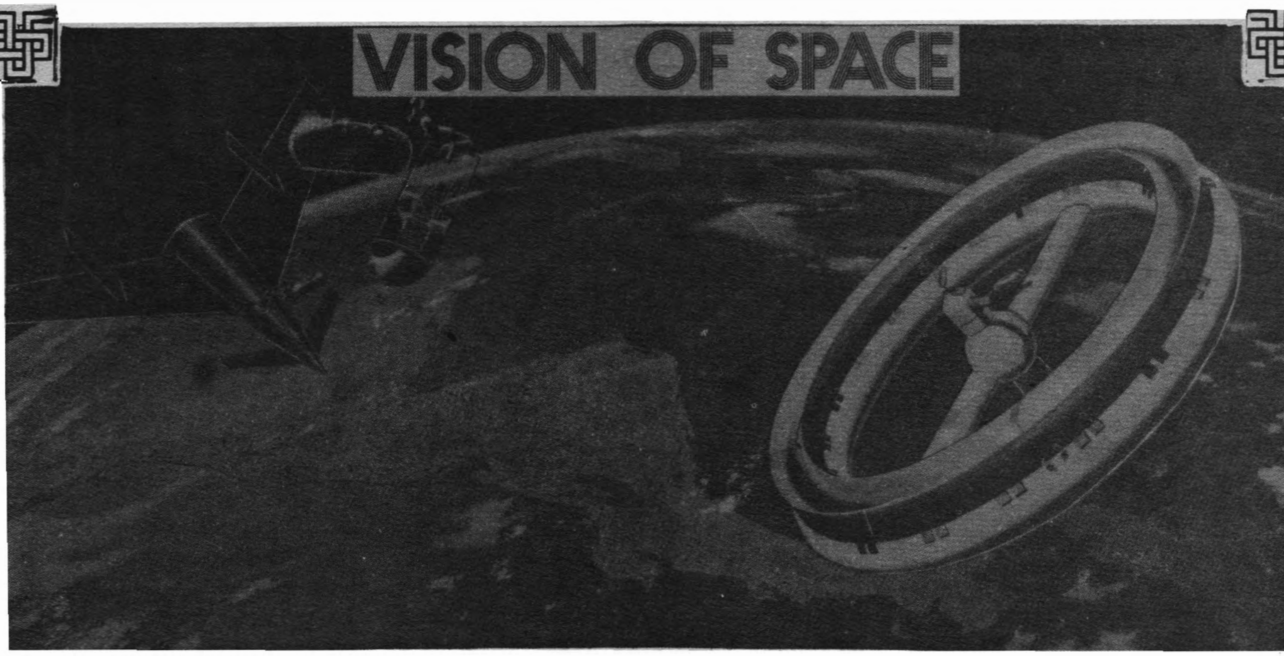

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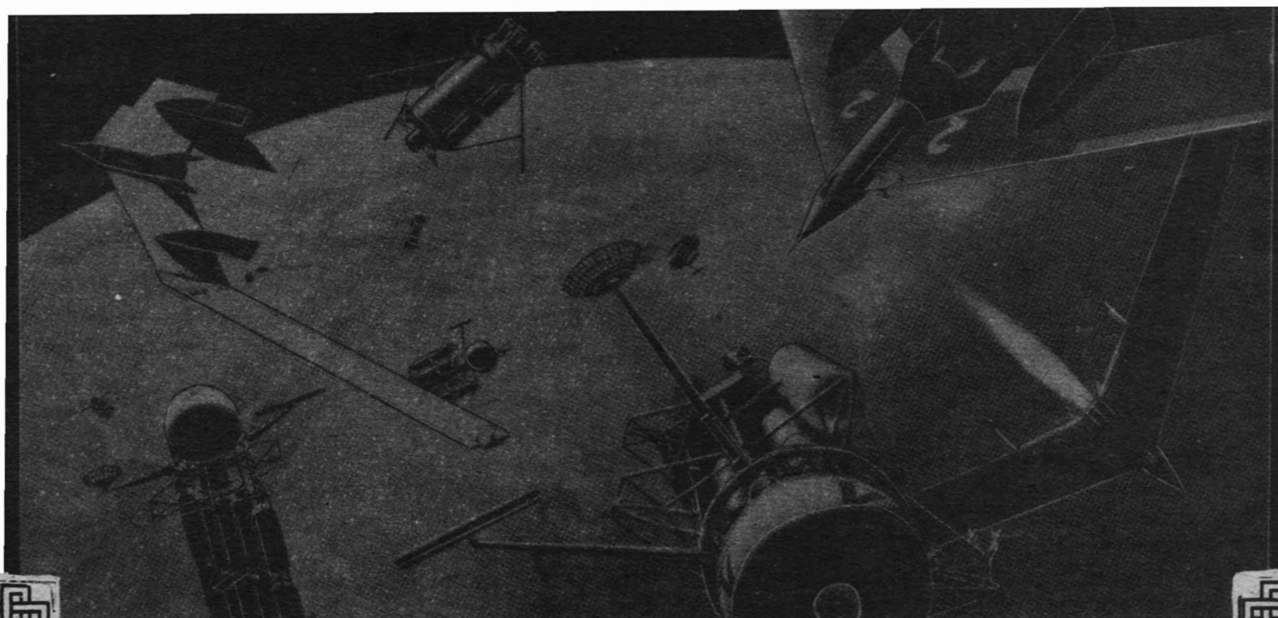
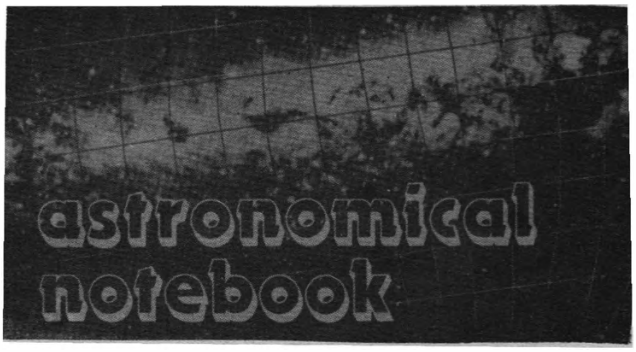




By Prof. John Griffith of Lakehead University, Ontario, Canada.

GALAXIES UNDERLYING QUASARS

As time progresses it appears more likely that quasars are unresolved Seyfert I galaxies. The same active galaxy that at low redshift would be classified as Seyfert would be considered a quasar at a redshift larger than 0.1 to 0.2, when the surrounding galaxy would be too faint to be easily recognised. M.A. Malkan of Palomar Observatory, B. Margon of the University of Washington and E.A. Chanan of Columbia University, writing in "The underlying galaxies of X-ray-selected quasar," *Astrophysical Journal* **280**, 66-78, 1984, obtained deep red images of 24 X-ray selected quasars, using the Palomar 1.5 m telescope. Over half yielded resolved structures centred in the pointlike quasar nucleus, with the light from the extended region being starlike. The host galaxies are usual normal spiral galaxies.

H.K.C. Yee of the Dominian Astrophysical Observatory and University of Arizona, and R.F. Green of the University of Arizona, in their paper "An imaging survey of fields around quasars. II. The Association of galaxies with quasar," *Astrophysical Journal* **280**, 79-90, 1984, analyse the properties of galaxies in small fields around quasars with redshifts from 0.05 to 2.05. They find that compact, high-central-density groups or small clusters of galaxies are the preferred sites for quasar activity.

These researchers, again using the Palomar 1.5 m telescope, obtained images centred on 108 quasars of control fields, 1° north of each equator.

They confirm the cosmological nature of quasar redshifts and find an overall excess association of galaxies with quasars. The excess galaxies appear to be situated at the same cosmological redshifts as the quasars. High redshift quasars do not have visible associated galaxies, presumably because they are too distant (and hence too faint) to be detected. The rate of detection of a nebulous component around the quasar decreases with distance.

There is a high galaxy density near quasars. The authors are undertaking more work on the properties of the associated galaxies to bring about a better understanding of the effects of global environment on the formation, maintenance and properties of quasars.

EXTRAGALACTIC RADIO SOURCES

Recently, the types of emission from extragalactic radio sources have been increased from the two well-known classes to three. Extended radio components with steep spectra and typical sizes over 100 kpc were one of the well known types, with compact nuclear components, sizes less than 1 pc and flat spectra the other. The third class are intermediate between the first two in size (around 1 kpc) and have steep radio spectra. Their size makes them smaller than a typical galaxy (which is of the order of 25 kpc).

This new source has been christened steep-spectrum cores (SSCs) and sometimes occur in combination with very extended and/or compact radio emissions. Nearly all SSC's are associated with relatively gas-rich galaxies, such as Seyferts; peculiar galaxies with rotating gaseous disks and dustlanes and/or neutral hydrogen; or cooling X-ray coronae. In several of these cases there is direct evidence of interaction between the SSCs and their environment.

More distant quasar-SSCs may be more powerful, but otherwise similar, objects. The properties of SSCs may often be explained in terms of jets propagating through a dense interstellar medium.

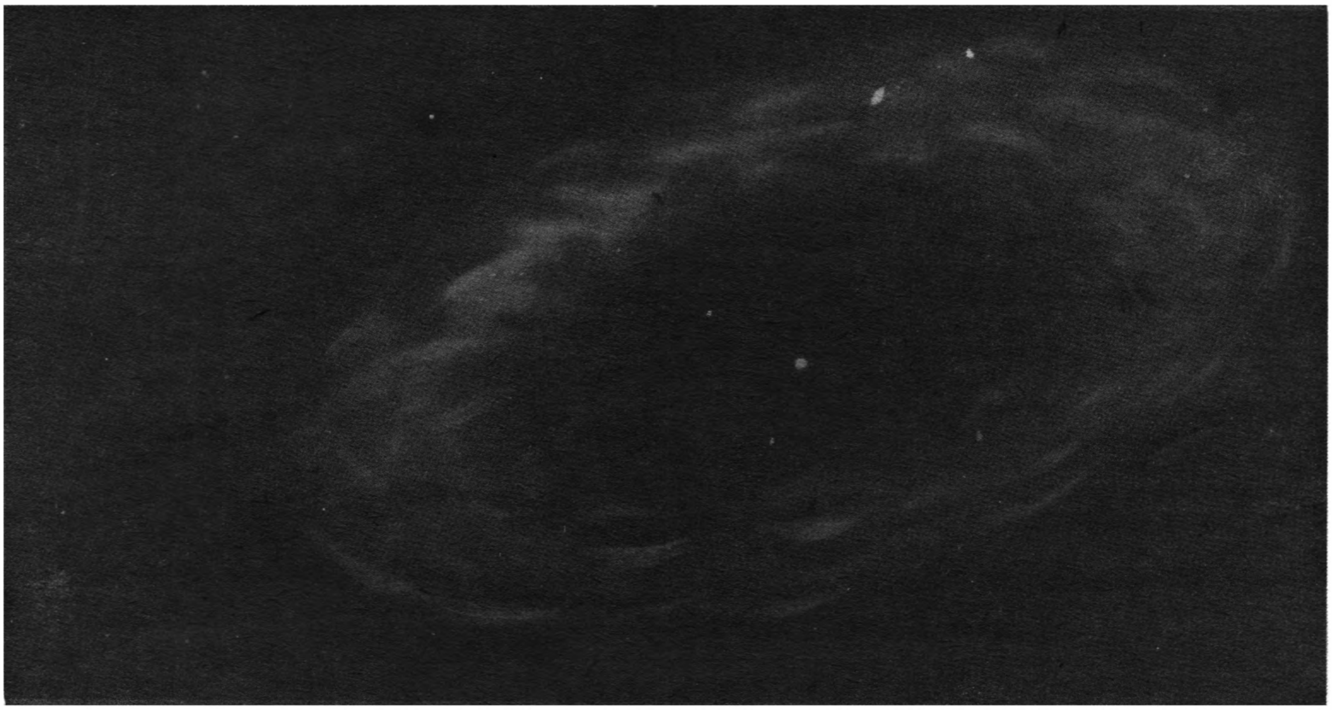
Using the VLA (Very Large Array at the US National Radio Astronomy Observatory) W. van Breugel of Steward Observatory, G. Miley of Leiden Observatory and T. Heckman of the University of Maryland obtained high resolution maps of the structures and polarization distributions of some of a sample of 23 powerful SSCs (mostly quasars). In their paper "Studies of Kiloparsec-scale, Steep-spectrum radio Cores. I. VLA maps" in *Astronomical Journal* **89**, 15-22, 1984, they list such items as positions, sizes, flux densities and polarization parameters, together with giving contour maps.

From analysis of the observations they suggest that these objects contain relatively dense ionized gas and that, generally, SSCs are embedded in dense gaseous environments. They seem to be due to jets propagating through dense and inhomogenous stellar material. The jets collide with clouds, heating and accelerating the ambient gas. This would account for the bright radio emission (shocks in the jets), wide emission lines (accelerated clouds), depolarization (entrained clumpy gas), the steep-spectrum turnover and the distorted structure/bending of jets by rotating gas or collisions with massive clouds.

Further study is suggested.

POPULATION III STARS

Traditionally, two populations of stars have been recognised. Population I stars are younger, typical of the spiral arms with relatively high abundances of metals, having formed from hydrogen contaminated by the debris from supernovae. Population II stars are older, typically found in the galactic halo and with a very low abundance of metals. Population III stars would be even older, perhaps pre-galactic in origin. They may be as massive as 100 solar masses. The cosmological consequences of the existence of such stars is discussed by B.J. Carr of the Institute of Astronomy, Cambridge; J.R. Bond of Stanford University and W.D. Arnett of the University of Chicago in "Cosmological Consequences of Population III stars," *Astrophysical Journal* **277**, 441-469, 1984, where they point out that pre-galactic very massive stars would leave black hole remnants. The effect of these remnants is discussed and could provide the 'missing mass.' Distortions in the 3 K background radiation are expected and the consideration of the associated effects places strong constraints on the mass spectrum and formation epoch of Population III stars. In particular, observations



Large amounts of material were observed by the Infrared Astronomical Satellite orbiting several stars, among them Vega. The IRAS resolution was not high enough to detect planets.

of spectral distortions in the 3 K background, the far-infrared background spectrum, the lower bound in the metallicities of Population III stars, various abundance anomalies and a gravitational wave background would enable a better determination of the possible existence and characteristics of Population III stars to be made.

STAR FORMATION

Stars form in molecular clouds but, as a consequence of the heavy obscuration, it is difficult to observe the initial stages of stellar formation in optical wavelengths. Using radio wavelengths, the flux from the associated HII regions may be observed and the Lyman alpha output obtained. From this the spectral type and luminosity of the ionizing stars may be obtained. V.A. Hughes of Queens University (Canada) and J.G.A. Wouterloot of Sterrwacht, Leiden used both the Westerbork Synthesis Radio telescope and the National Radio Astronomy Observatory's Very Large Array to observe the molecular cloud Cepheus A. Their work is reported in 'The star-forming region in Cepheus A,' *Astrophysical Journal* **276**, 204-210, 1984, where they describe a cluster of about 14 compact HII regions contributing to the total radio flux from the eastern source of Cep A. The radio peak is displaced from the infrared peak, where a number of pre-main sequence objects, incapable of ionizing their surroundings, appear to exist.

The formation and elongation of the HII regions is along a line and the authors propose that the collapsing cloud led to a prolate spheriod with the magnetic field aligned along the axis. A field of 3.5 milligauss has previously been reported; such a field could contain various HII regions. There are two strings of HII regions, each about 0.1 pc long. If the stars are equivalent to main sequence stars, the 14 regions can each be attributed to a B3 star, of age around 1000 yrs, separated in some cases by as little as 1000 AU. Binary stars are predicted, with some stars coalescing into more massive stars. Further star formation is expected.

RAPID QUASAR VARIATIONS

Albert D. Grauer of the Louisiana State University, using the 91 cm reflector at Kitt Peak National Observatory, reports in his paper "Evidence for Rapid Optical Variations of the Quasi-stellar Radio Source 4C 19, 45" (*Astrophysical Journal* **277**, 77-81, 1984) that this object of apparent magnitude 17 displays rapid brightness variations on the order of 0.02 days or less. This, in turn, implies a size of the emitting region of the order of 30 light minutes. A model of a 10^7 solar mass black hole surrounded by an accretion disk 30 light minutes in radius and a mass of 10^6 solar masses appears to fit the observations.

GRAVITATIONAL IMAGING

Most of the visible matter in the Galaxy appears to be located in superclusters of galaxies. These are long, thin filaments separated by voids of similar extent. Their length ranges from 10 to 100 Mpc. In their paper "Gravitational Imaging by Superclusters," (*Astrophysical Journal* **278**, 291-294, 1984), R.H. Sanders, T.S. van Albada and T.A. Oosterloo consider the effects of the gravitational lens effects of such thin filaments.

They point out that the importance of gravitational imaging by superclusters is critically dependent upon properties of the superclusters which are, at present, uncertain. Until the typical perpendicular scale height and mean line density are known, we are unable to predict their effects accurately. However, we may be able to estimate the unknown parameters from specific examples of gravitational imaging.

There are already several possible examples available, ranging from groups of three quasars and three radio sources to the general tendency of extended radio sources to be parallel if they lie within 10° of each other.

The presence or absence of galaxy or radio source alignments will constrain the properties of superclusters.

41D: THE DEBUT OF *DISCOVERY*

By John A. Pfannerstill

Following the excitement of Spacelab, the first Manned Manouvering Unit flights and the repair of Solar Max on the previous three Space Shuttle missions, the twelfth Shuttle flight, designated Mission 41D, was to be a return to the 'routine' business of delivering satellites and flying scientific and technological payloads. On the agenda was the deployment of one satellite, the testing of a new, ultralight solar array, Earth photography and commercial drug processing.

Introduction

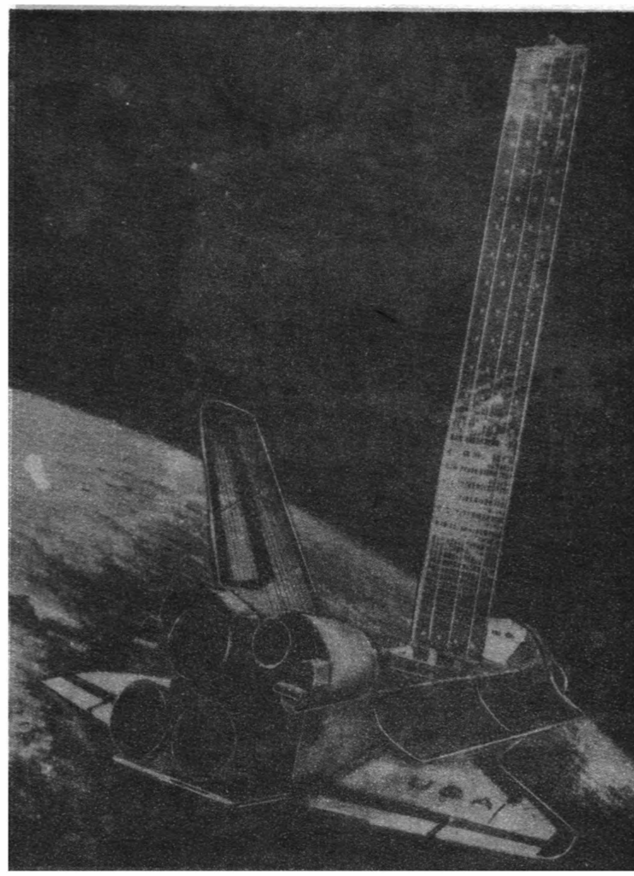
Mission 41D marked the inaugural flight of Orbiter OV-103, *Discovery*. Although it looked almost identical to its sister ships, *Discovery* was much improved. Over 3,000 kg less massive than *Columbia* and 300 kg lighter than *Challenger*, it had weight-saving fabric thermal protection system blankets covering most of the upper fuselage and wings, replacing many of the heavier tiles of its predecessors. To shave off more weight, *Discovery* also used graphite epoxy structural elements in its main body construction instead of the more massive aluminium beams. Its unfuelled and unloaded weight was 67,100 kg.

In addition to being the first flight of a new Orbiter, 41D also marked the first time that a commercial paying passenger was included on a crew. McDonnell Douglas requested that one of its engineers, Charles D. Walker [a BIS Fellow-*Ed.*], went along to operate its new improved version of the Continuous Flow Electrophoresis System (CFES). The CFES was carried on an experimental basis on four previous Shuttle missions, processing only small quantities of test materials but, since its last flight, the 288 kg unit went through major modifications, enabling it to produce large amounts of medicines and vaccines which Johnson & Johnson and Ortho Pharmaceuticals Corporation hope to market commercially by the late 1980's. Its operation was expected to take up a considerable portion of crew time and so McDonnell Douglas argued successfully that time and money would be saved by sending one of its own engineers along. As one of CFES' designers, Charlie Walker was the obvious choice. McDonnell Douglas was charged $80,000 by NASA to finance his basic Shuttle training, which included instruction in emergency procedures and operation of the Orbiter's living accomodations. For Walker, it was a once-in-a-lifetime opportunity and, as training progressed, he quickly became less a part of the payload (which he technically was) and more a member of the crew.

The NASA crew was made up of four 'rookies' and one veteran. Henry W. Hartsfield, who previously flew in June 1982 on STS-4, headed the team as mission commander. His crew included USN Commander Michael L. Coats, the Pilot, as well as three Mission Specialists: Lt. Col. Richard M. Mullane (MS-1), Dr. Steven A. Hawley (MS-2) and Dr. Judith A. Resnik (MS-3). Resnik was to become the second American woman to go into orbit, alongside Hawley, the husband of the first US space woman, Sally Ride.

For the first mission, *Discovery* carried a varied payload:

1. Syncom IV-1 communications satellite;
2. NASA's Office of Aeronautics and Space Technology (OAST-1) payload;
3. Large Format Camera (LFC-1);
4. Continuous Flow Electrophoresis System (CFES-BLOCK III);
5. Cinema-360 and IMAX motion picture camera payloads;
6. One Getaway Special (GAS) payload;
7. One Shuttle Student Involvement Project experiment;
8. Two science and technology experiments, the Vehicle Glow Experiment and the Clouds Experiment.



An artist's impression of the Solar Array Flight Experiment. *NASA*

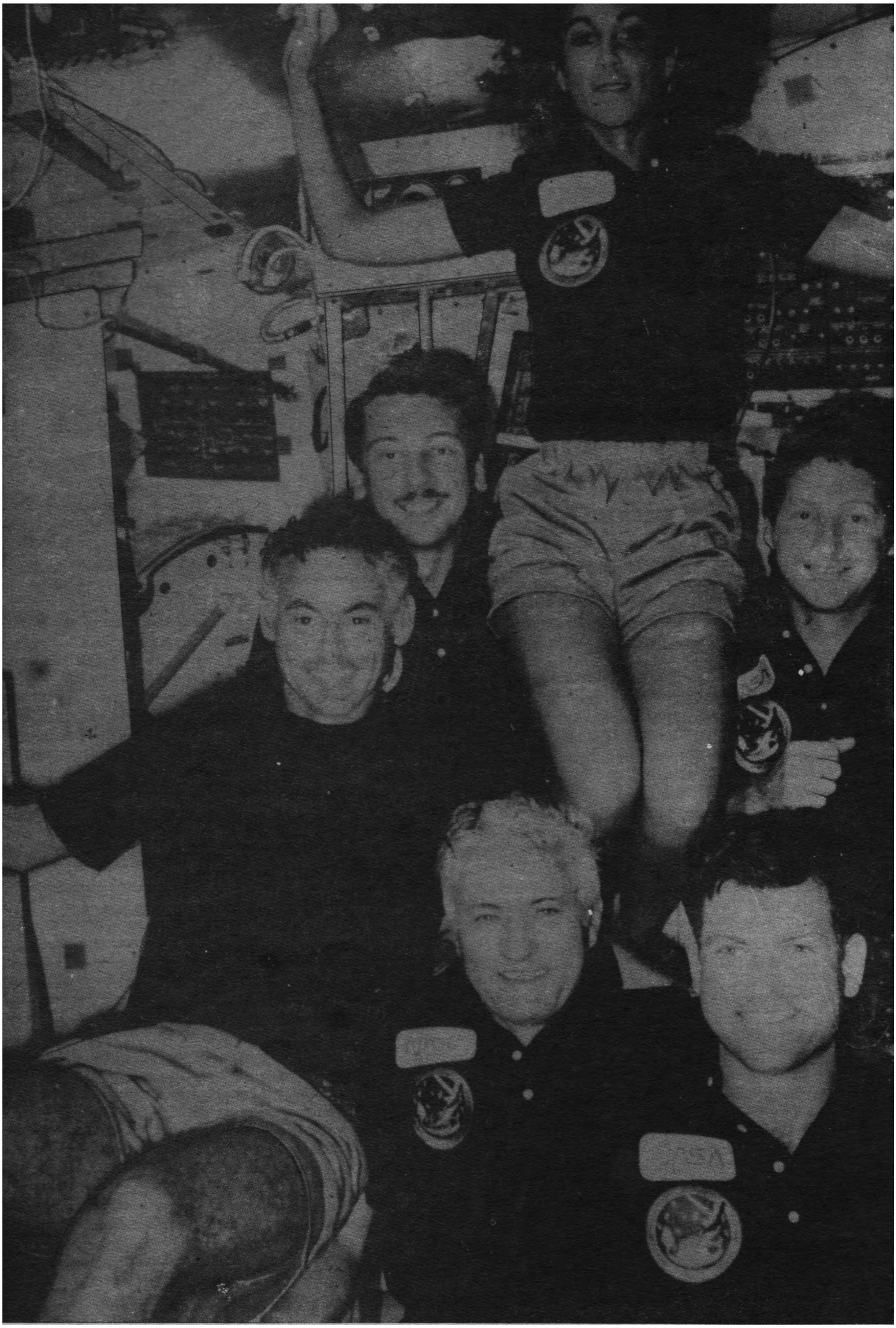
The mission was planned to last for seven days with a landing at Edwards Air Force Base in California. Launch was scheduled for 25 June 1984.

False Starts

The countdown began at 07:00 GMT (all times GMT) on 23 June and went extremely well. The targetted launch time was 12.43 on 25 June with a 45 minute launch window dictated by deployment constraints on the Syncom satellite.

On the morning of 25 June, *Discovery's* first crew went through the familiar launch-day route of breakfast, the ride to the pad and boarding the Orbiter. Everything was going strictly by the book until shortly before launch when a problem was noted in *Discovery's* backup computer. Engineers studied data from the computer in the hope that the trouble could be resolved, but it could not. The

The 41D crew pose in *Discovery's* middeck. Clockwise from top they are, Judith Resnik, Steven Hawley, Michael Coats, Henry Hartsfield, Richard Mullane and Charles Walker.



mission was scrubbed for the day at 12:35, just eight minutes away from the scheduled liftoff.

The disappointed astronauts were taken out of the Orbiter and the propellants were drained from the External Tank. Technicians then went out to Pad 39A to check the computer and found that the suitcase-sized unit had suffered a hardware failure. A replacement was 'cannibalised' from *Challenger* and installed in time for a launch attempt the next day.

On 26 June, the crew went through exactly the same routine a second time. As they strapped themselves in, the only problem was the weather. At daybreak the pad was completely enshrouded in thick fog, making the Shuttle completely invisible to the spectators at the press site but as the Sun came up, the mist began to lift and, as the 12:43 launch time approached, there were hazy blue-white skies overhead.

The countdown passed the critical point at which the backup computer failure had occurred the day before and everything was in fine shape as launch control commentator Mark Hess counted down the final seconds.

'Ten... we have a GO for main engine start... seven, six, five... we have main engine start... we have a cutoff... we have an abort by the on-board computers of the Orbiter *Discovery!*'

Observers saw a brief puff of steam from the Shuttle main engine exhaust, accompanied by a gasp-like roar that quickly died away. The smoke and vapour slowly drifted off, leaving *Discovery* sitting forlornly in the morning sunshine.

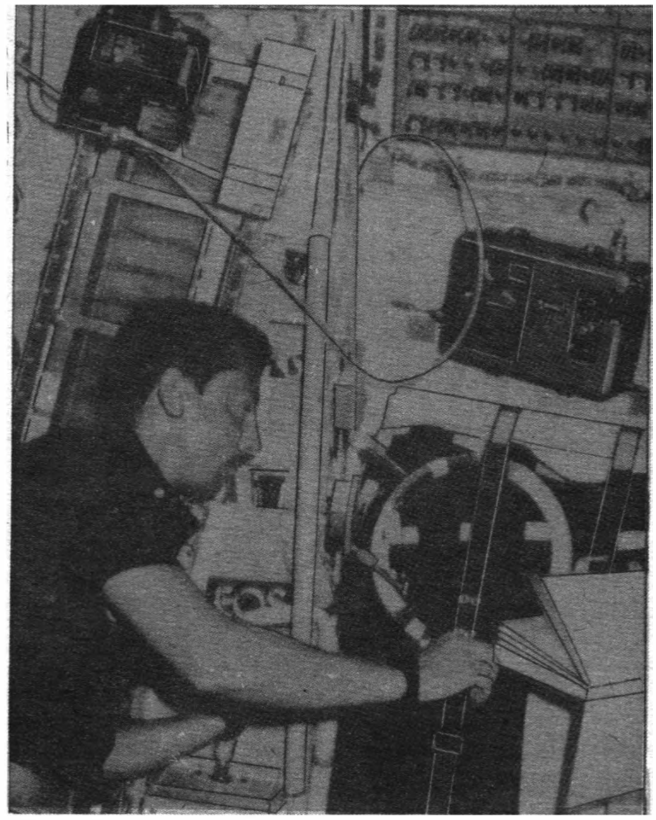
Up in the cockpit, the astronauts felt vibrations as the main engines lit up, accompanied by audible engine malfunction alarms in their headsets. Veteran commander Hartsfield said later, "I knew we weren't going anywhere."

It became apparent that two of the three main engines ignited in the normal one-at-a-time 'ripple-fire' sequence employed on all flights. However, before the third could fire up, *Discovery's* computers sensed that something was amiss in one of the two engines already firing and so they called an automatic halt to the countdown, shutting everything off at the T-4 sec mark. This was exactly what the computers were programmed to do and they performed their function flawlessly.

At this point, Hartsfield said later, the crew's main concern was making sure that the Solid Rocket Boosters would not ignite accidentally. Unlike the main engines, once the SRBs ignite they cannot be shut down. In such a situation, *Discovery* would *have* to lift off, main engines firing or not. The spacecraft would probably ditch far downrange in the Atlantic. As it turned out, however, there was no reason for concern. The computers continued to do their job, automatically saving the SRBs and putting *Discovery* into a condition in which nothing could accidentally start.

Suddenly, just as controllers were starting to relax and take stock of the situation, TV monitors showed a fire burning on the underside of the Orbiter's tail, near the body flap. Fire detectors at the pad subsequently confirmed the blaze and an effort was made to put it out using high-pressure water nozzles. The flames were doused and the water was turned off. The fire started up again and the water had to be switched back on. This happened three times.

Controllers were faced with a highly dangerous situation. The External Tank was still fully loaded with over 700,000 kg of propellant capable of exploding within seconds if touched off by the fire. Hartsfield, as well as Launch Director Bill Sieck, considered an emergency evacuation of the Orbiter. This would involve the six astronauts quickly leaving *Discovery*, running across the Orbiter Access Arm to a cab mounted on a slide-wire, and then riding in the cab to the ground a few hundred metres away. From there, they would be quickly driven out of the area in an armoured vehicle. In the final analysis, Hartsfield decided to sit tight. There was the possibility that toxic gases might be present around the Orbiter. In that event, it would be safer for the crew to stay aboard as long as there was no immediate danger.



Payload Specialist Charles Walker hard at work with his CFES equipment in *Discovery's* middeck.

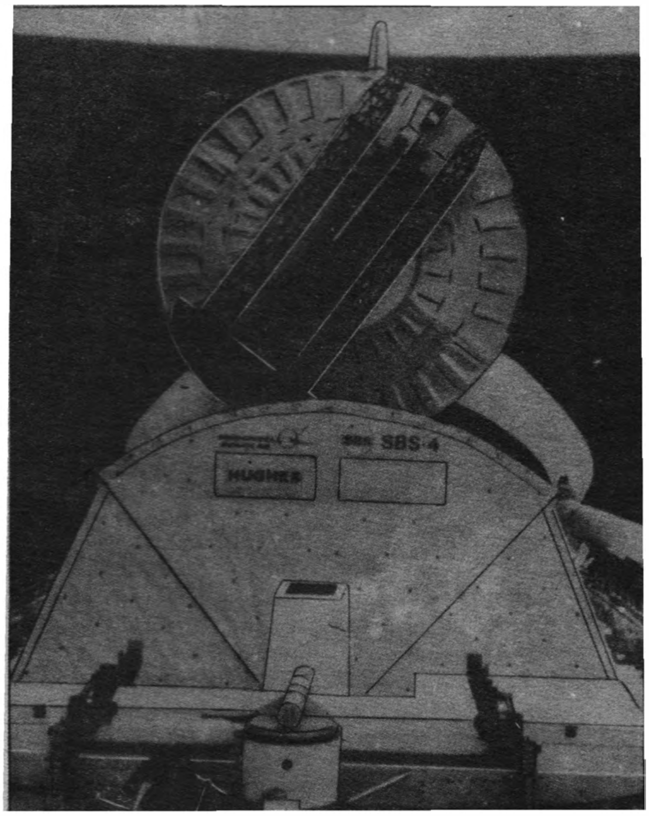
As soon as it was deemed safe, a crew of technicans went out to the pad to get the astronauts out of the Orbiter. Some of the crew members looked visibly shaken and tense as they emerged from *Discovery's* hatch some 40 minutes after the incident. There was no milling around. The astronauts rapidly doffed their helmets and were led quickly out of the White Room.

With everyone safe, Shuttle managers set off on the difficult task of trying to determine what had gone wrong. It was obvious that there had been a very serious malfunction and that there would probably be a delay on the order of several weeks. The astronauts returned to Houston while engineers and technicans converged on *Discovery*.

Regrouping

The first order of business was to understand exactly what had happened. In a normal Shuttle main engine start sequence, Engine 3 ignites first, followed by 2 and then 1. As soon as the Orbiter's computers confirm that all three engines have reached full thrust, the SRB start command is given and the Shuttle is on its way.

In the 26 June abort a problem developed in Engine 3. It was theorised that when it went through its start sequence at T-6.6 seconds, pieces of microscopic contamination caused the Main Fuel Valve in the engine to malfunction. In the meantime, Engine 2 started normally and the computers were just about to send the ignition command to Engine 1 when they noticed the problem



Lying on its side with its top toward the camera, Syncom IV-2 is launched 'Frisbee-style' from *Discovery*.

in No. 3. As programmed, they shut everything down immediately, leaving the count in a hold at T-4 seconds. Meanwhile, the excess hydrogen in the area following the brief engine startup was deemed to be the cause of the fire seen at *Discovery's* tail. The only damage to the Orbiter was that some of the vulcanising material used to treat the tiles on the body flap was burned off and had to be re-applied. The ET and SRBs came through unscathed.

The main problem facing the engineers and technicians was how to deal with Engine 3. They attempted to duplicate the failure in ground tests, but were unable to do so. As a result, instead of simply replacing the faulty valve it was decided to replace the entire engine. The changeout was done at the pad and completed on 5 July.

Shuttle programme scheduling presented mission managers with still more problems. At the time of 41D's originally scheduled launch, NASA was planning a rather ambitious programme of four more flights before the end of the year. This hectic pace was severely affected by 41D's failure. The planners decided to combine most of 41D's original payload with some of the items scheduled to fly on *Discovery's* second mission, 41F, which was then set for the end of August. Thus, plans proceeded to fly 41D in the late August time slot with Hartsfield's crew and the following D/F hybrid payload aboard:

1. Syncom IV-2 communications satellite (from 41F);
2. Satellite Business Systems (SBS 4) communications satellite (from 41F);
3. Telstar 3 communications satellite (from 41F);
4. NASA's OAST-1 payload (from 41D);
5. Continuous Flow Electrophoresis System (CFES-BLOCK III) (from 41D);
6. IMAX Motion Picture Camera system (from 41D);
7. One Shuttle Student Involvement Project experiment (from 41D);
8. Two science and technology experiments, Vehicle Glow and Clouds (from 41D).

To make room for these additions from 41F, Syncom IV-1, the LFC, Cinema-360 and the GAS payload were all dropped from the mission to be re-assigned to flights some months down the line. Likewise, the remainder of the 41F payload, as well as astronauts Bobko, Williams, Seddon, Hoffman and Griggs, were given other assignments. Mission 41F was formally cancelled.

Discovery was rolled back to the Vehicle Assembly Building on 14 July where it was de-mated from the ET and transferred to the Orbiter Processing Facility. There it underwent modifications to its payload bay to permit the cargo changes. The re-stacked vehicle was then moved back to Pad 39A on 9 August where its new payload was installed two days later.

Thus outfitted with a new cargo and a slightly different mission, *Discovery's* second countdown began on 27 August, aiming toward a 12:35 liftoff on 29 August.

Further trouble cropped up late on 28 August that caused a 24 hour postponement. The problem consisted of a timing error in *Discovery's* Master Events Controller, a device that commands many critical vehicle functions during flight. There were fears, that if gone uncorrected, the timing discrepancy could have prevented the SRBs and ET from separating during ascent. Johnson Space Center computer experts designed a software 'workaround' and the launch was re-scheduled for 30 August at 12:36.

Mission Day 1: 30 August 1984

A year after *Challenger* began its third mission by lighting up the night sky in the first after-dark Shuttle launch, *Discovery* leaped off the same pad to start its maiden voyage. Liftoff came at 12:41:50, having been delayed nearly seven minutes by a stray Piper Aztec aircraft that had wandered into the restricted airspace around the Kennedy Space Center.

Because of the lightweight structure, the new Orbiter's computers programmed an ascent profile that put less stress on the wings and tail. Throttling of the main engines was done in steps and a more gentle angle of attack was selected. Main engine performance was good and after cutoff and two Orbital Maneuvering System burns, *Discovery* and her crew found themselves in a 296 km circular orbit inclined at 28.45° to the equator.

As on all Shuttle flights, the first order of business was getting the payload bay doors open again. As *Discovery* was a new Orbiter, extensive door opening tests were conducted. This also marked the first flight for a new Remote Manipulator System (RMS) arm, so Mission Specialist Judy Resnik unlimbered it and put it through its paces about 3½ hours after liftoff. "The arm works super," she concluded. Some initial checks of the CFES were also done, handled entirely by 41D's passenger, Charlie Walker.

The main order of the day, however, was the deployment of SBS 4, an operation taken care of by Mike Mullane and Steve Hawley. The 3,349 kg cylindrical satellite spun up and out of *Discovery's* payload bay at 20:40 in a precision deployment that was followed 45 minutes later by an equally exact 85 second PAM engine burn. The astronauts used one of the RMS television cameras to observe the manoeuvre from their vantage point 20 km away.

There had been concern about how well the PAM would perform. The two satellites were lost on Mission 41B in

February 1984 because of failed PAM engines but there was no cause for alarm this time. The solid propellant stage worked perfectly, putting SBS 4 into a good geostationary transfer orbit. An engine aboard the satellite itself later fired on 1 September, putting SBS into a stationary position over the equator some 35,880 km high.

The only problem noted with *Discovery* involved a faulty Cathode Ray Tube screen on Pilot Mike Coats' side of the cockpit, but plans were being developed to replace it with a tube from the aft payload control console. It was planned to make the change just before entry, so that Coats would have it available for landing.

Mission Day 2: 31 August 1984

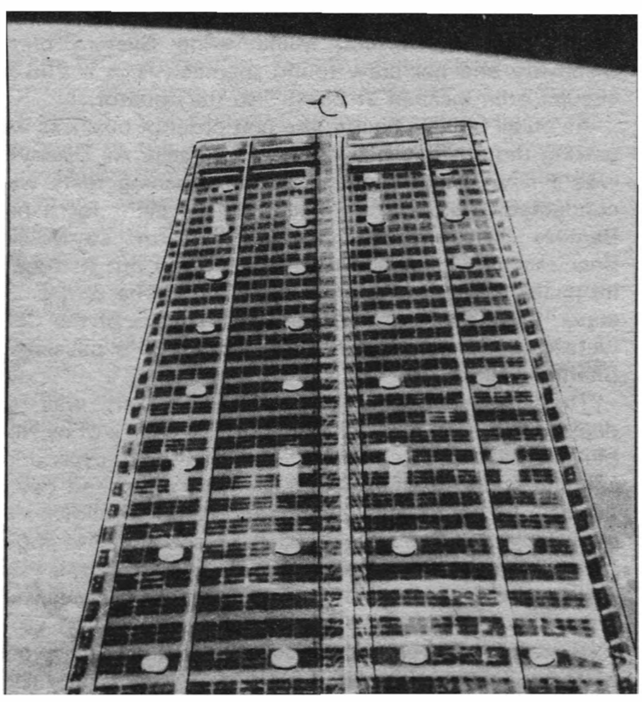
Awakening to the strains of 'Anchors Aweigh,' the US Navy theme song, the crew began their day by getting ready for the second satellite deployment.

The deployment of Syncom IV-2 was to be very different from that of SBS 4. Much of the difference lay in the fact that Syncom was of a radically different design. Built specifically to be launched from the Shuttle, the satellite rested on its side at the far end of the payload bay. Instead of being spun up inside the bay and then pushed out vertically as SBS has been, Syncom was designed to be flung out of the bay on its side at a very slow rotation - much like the popular 'Frisbee' flying disc. In fact, NASA officially referred to it as the 'Frisbee Deploy' method. Nor did Syncom use a separate upper stage to boost it into geostationary transfer orbit. It carried its own self-contained propulsion unit and could travel itself all the way from the Shuttle's 296 km orbit up to geostationary altitude.

Again, Mullane and Hawley were in charge. At 13:10, Hawley threw switches to retract the pins holding the satellite in the payload bay. Three minutes later, Mullane commanded the deployment. The Orbiter was flying upside down and in the views transmitted from the RMS television cameras, Syncom IV-2 appeared to be dropping 'down' toward the Earth in a slow 2 rpm rotation as it left the bay at 0.46 m/s.

The astronauts watched the satellite depart against the beautiful blue background of the Earth. They were able to observe Syncom's omni antenna mast extension some 80 seconds after deployment and about five minutes after that they were able to see the satellite increase its rotation rate to 33 rpm by using small hydrazine thrusters.

The OAST-1 solar array at nearly full extension.



At 13:28, Hartsfield and Coats made a small OMS burn to put *Discovery* at a safe distance in preparation for Syncom's perigee kick manoeuvre at 13:58. The satellite's modified Minuteman 3 engine worked perfectly, burning the full 59 seconds and putting it on target. Three additional manoeuvres, all performed by the liquid propellant engine, were planned over the next few days in order to place Syncom in position over the equator at about 100° West longitude.

The second day of the flight also marked the start of payload specialist Charlie Walker's processing work with the CFES. However, less than one hour into his 80 hours of planned work, the large drug processor automatically shut itself off after exhibiting 'wildly divergent pressures.' Walker started it back up only to have to stop it manually a few minutes later when the pressures again started to fluctuate. He tinkered with the unit for some time, along with experts on the ground who studied other data in an effort to find out what was wrong. McDonnell Douglas engineers promised to keep working overnight, hoping to pass a solution up to Walker in the morning.

Mision Day 3: 1 September 1984

Shortly after the crew awoke, Walker was on a communications headset talking to McDonnell Douglas' deputy CFES programme director David Richman. Richman gave him some recommendations, but there was no clear-cut resolution. The CFES continued to operate erratically in the automatic mode. Walker eventually resorted to manual operation, which required a great deal more work on his part, but by the end of the day things seemed to be going well and Walker appeared to be making up much of the lost time.

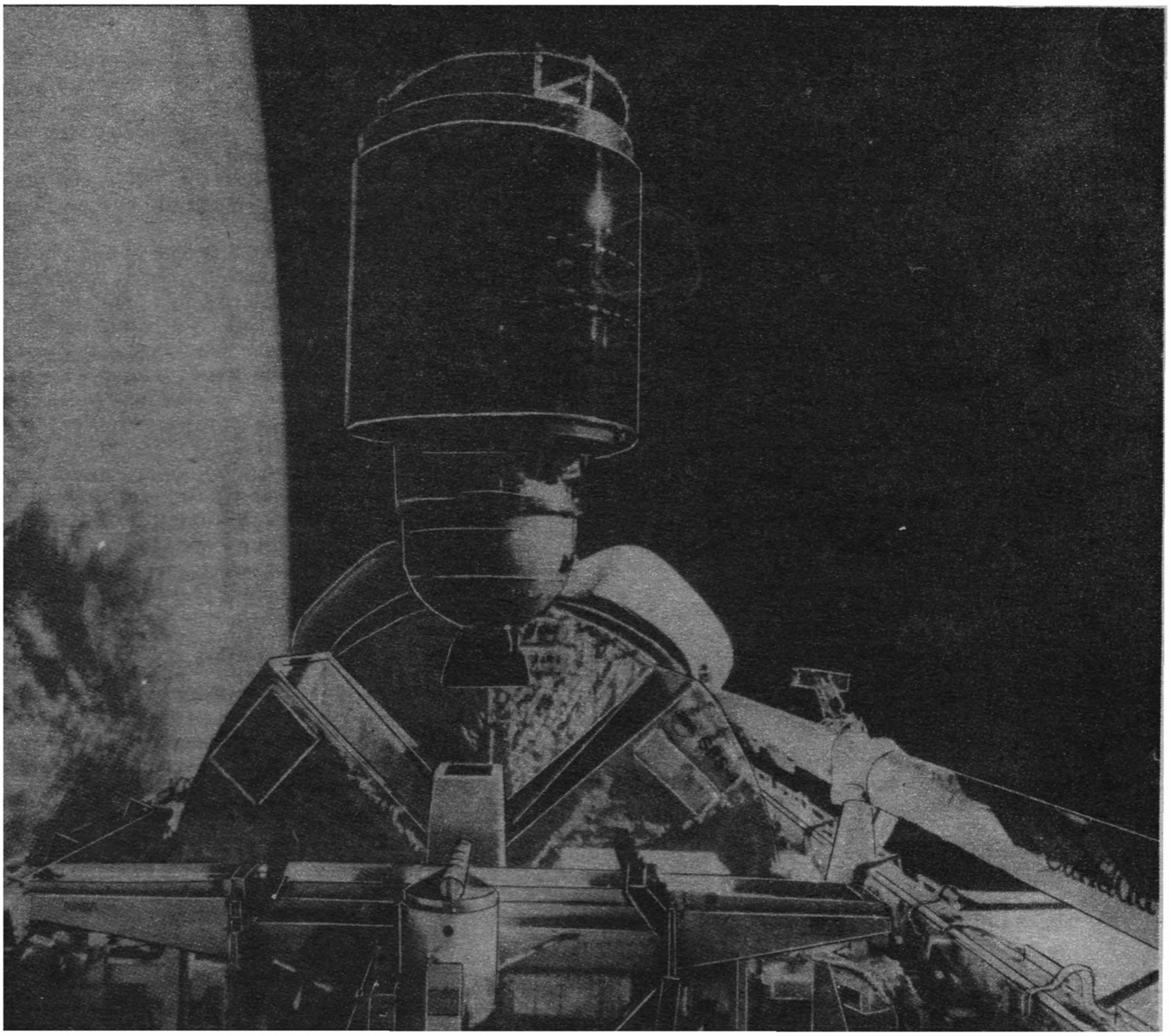
The other astronauts also had a busy day ahead. Resnik planned to begin operations with the OAST-1 Solar Array Experiment and Hawley and Mullane had their third and final satellite to launch.

The Telstar 3 satellite, set for deployment during *Discovery's* 33rd orbit, was almost a twin of SBS 4. The astronauts started Telstar spinning at 50 rpm and then threw switches to spring it vertically out of the payload bay at 0.9 m/s. Final departure took place at 13:24. Once again, Hartsfield and Coats backed *Discovery* away to a safe distance from which the PAM perigee burn could be observed by the RMS cameras. The solid stage ignited right on time at 14:09 and burned perfectly for the full duration. *Discovery's* satellite delivery mission was now complete. The crew had achieved a perfect 'three for three' record and it was time to move on to other activities.

On the agenda for the remainder of the day were two extension tests of the large 31 m solar array that was part of the OAST-1 package. For these first two deployments, however, the wing would be raised only to 70% of its full length (about 22 m).

Resnik began the first extension at 17:30 as *Discovery* passed over Hawaii on its 36th orbit. The ultralight wing was folded up accordion-style inside a shallow box only 18 cm high. It was slowly pulled out of the box by a lightweight fibreglass mast that extended at a rate of 3.8 cm/s. The principle was much the same as that employed by portable home movie screens.

Hawley observed that the 84 plastic panels making up the array seemed to stick to one another as they emerged from the stowage container. He assumed that this was due to the many weeks that they had been folded since



The SBS 4 satellite rises out of the payload bay on the first day of the mission.

their last ground test deployment. The sticking was not observed on subsequent extensions.

The panels pulled apart properly, however, and after 9 minutes the wing towered 22 m over the Orbiter's payload bay. 'It's up and it's big!' Resnik exclaimed, adding that the array was 'very steady and stable.' After a few minutes, Resnik retracted the wing to make sure that it would fold properly, which it did. She then initiated a second extension to the 70% position, this time to observe how it would behave when shaken by *Discovery's* thruster firings. The wing appeared to be very stable. It swayed somewhat but the astronauts said that the action of deploying it actually shook it more than did the thruster bursts.

The tests concluded a very busy day for the crew, who bedded down for their third night in space shortly after the wing was re-stowed in its box.

Mission Day 4: 2 September 1984

Day 4 was a little more relaxed. Mullane and Hawley took advantage of some of the free time to make and fly zero-g paper aeroplanes down in the middeck area. One of them had even brought along a Frisbee and the two mission specialists played a weightless game of 'catch' for the benefit of the TV audience on Earth.

It was not all play, however, and Charlie Walker continued to be a very busy man. His manual CFES processing activities were continuing and seemed to be producing good results. He took a small sample of the material he was making, ran some tests on it and confirmed that the quality was as good as the CFES investigators had hoped it would be. McDonnell Douglas would later assert that had Walker not been aboard it is probable that no material would have been obtained.

Meanwhile, Resnik put in a second day of work with the OAST-1 solar array. She first extended it once more to the 70% position for additional dynamics tests before finally raising it up to its full 31 m length. Spectacular TV views were transmitted to Earth showing the shadow of *Discovery's* tail and OMS pods backlit through the thin plastic of the brilliant gold-coloured wing (*Discovery* was flying with her tail toward the Sun).

With the array up at its full extension, more dynamic tests were conducted to see how much the wing would sway. With each thruster burst, the top of the panel would swing back and forth about 50 cm. This was far less than predicted.

Late in the day, after the wing had been stowed, a totally unexpected problem cropped up that was to dominate most of the rest of the mission. It was found that a large chunk of ice was clogging a waste water dump outlet on the port side of the Orbiter. The crew

moved the end effector of the RMS arm over to the blockage so that it could be inspected with a TV camera. They found a 9 kg icicle roughly 50 cm long.

While the ice posed no threat to the crew, it did present a potential hazard to the Orbiter. On Mission 41B in February 1984 one of the OMS pods sustained substantial damage from an unknown source. Engineers theorised that just such an ice chunk had formed on that flight, only to break off during entry and fly back to hit the pod.

Hartsfield tried firing the RCS engines to shake the ice loose but it stayed stubbornly in place. Since it was getting close to bedtime, MCC-H controllers decided to have the crew orient *Discovery* with the ice block facing the Sun overnight in the hope that it would be gone by morning. They also gave the crew instructions not to use the toilet. Controllers feared that the waste management tanks would fill up with urine before they could be dumped overboard. Thus, the astronauts resorted to the plastic bags used during the old Apollo flights.

'We tried out the Apollo bags,' one of the crew announced shortly before bed, 'and we decided that those Apollo astronauts must have been real men.'

'You don't want to hear what Judy has to say,' added another.

Mission Day 5: 3 September 1984

After the astronauts awoke, one of the first things they did was to check on the ice. To their dismay, it had hardly melted at all. Hartsfield tried harder, sharper RCS firings in an effort to jar the block loose but his attempts were still unsuccessful.

MCC-H began working on alternate procedures. Astronauts Joe Engle, Ron McNair, Sally Ride and Bob Springer boarded the Shuttle Engineering Simulator at the Johnson Space Center to see what they could suggest. The most promising solution involved using the RMS arm very carefully to tap the icicle free. The problem was that in order to get to the ice chunk, the end effector had to be positioned in such a way that the astronauts would be unable to see it. Pictures from the arm's TV cameras were available, of course, but normal RMS operations are designed to use a combination of both TV and direct visual cues. Making matters worse, the ice was very near some critical thermal tiles on the leading edge of the left wing. Accidentally bumping them with the arm could cause significant damage. Arm clearance around the open payload bay doors and radiators would also have to be carefully monitored. In summary, Engle, McNair, Ride and Springer found that the method would work, but only with much difficulty. Ride said that she hoped another way could be found.

Up in *Discovery*, plans were being made for just that eventuality. Ride's husband, Steve Hawley, along with Mike Mullane, began pre-breathing pure oxygen just in case they might have to go outside to chisel the ice free. Hartsfield also lowered *Discovery's* cabin pressure to make an EVA easier but the main course of action decided on was to try the RMS method first. Only if that did not work would Hawley and Mullane make a spacewalk.

Mission Day 6: 4 September 1984

The crew was awakened early to allow them extra time in case of unforeseen problems in the ice chipping operation. Since it was to be such delicate work and the risk factor was fairly high, mission commander Hank Hartsfield operated the arm himself. He did not want any of his crew to have to take the blame if the Orbiter were damaged in any way. Resnik sat in the left front cockpit seat, craning her neck to look back down the side of the Shuttle in an effort to try to guide him visually but, for the most part, Hartsfield had to rely completely on the end effector TV camera.

As it turned out there was no need for worry. Hartsfield made the operation look easy as he carefully gave the icicle a tap with the arm. The block swiftly floated away and only a harmless 5 to 10 cm piece remained. This was not expected to cause any problems.

With MCC-H now calling them the 'Icebusters' (after the popular American film *Ghostbusters*), the crew began packing up to come home.

Walker shut down the CFES and flushed out its lines. Things had not gone completely according to plan for him, but still he estimated that he had obtained about 80% of the material he had hoped for before the flight. These were excellent results in the light of the earlier problems. He was also comforted in the knowledge that he would soon be getting another chance - Walker and the CFES are scheduled to fly on Mission 51D in March 1985.

The other astronauts also tidied up, unstowed seats and made preparations for entry. Hartsfield and Coats performed a check of *Discovery's* flight control system, pronouncing it to be in excellent shape. The weather was also cooperating, with excellent conditions predicted for Edwards Air Force Base.

Mission Day 7: 5 September 1984

While the astronauts were sleeping, just before 03:00, MCC-H detected an oxygen leak aboard *Discovery*. It seemed that one set of tanks in the cryogenic oxygen system was emptying three to four times faster than normal. Reluctantly, MCC-H awoke the crew 90 minutes early to have them correct the problem by isolating the leaking system. Oxygen was then drawn from a second redundant set of tanks.

For a time, flight controllers considered bringing *Discovery* down two orbits early because of the leak, but when things seemed to stabilise a decision was made to hold to the original plan.

Since this was the first flight of a new Orbiter, the wide expanse of Rogers Dry Lake at Edwards Air Force Base was chosen as the primary landing site. Touchdown was planned for just ten minutes after sunrise at the base with *Discovery* part way through its 97th orbit.

The six crew members donned their helmets and assumed their assigned seats. Pilots Hartsfield and Coats, who would be doing all of the flying, took the left and right hand cockpit seats respectively. Between and slightly behind them sat Steve Hawley, who was acting as flight engineer. To Hawley's right was Judy Resnik, and down below on the middeck sat Mike Mullane and Charlie Walker. For entry, Resnik and Mullane swapped places.

Discovery's first descent from space began with a perfect deorbit burn at 12:36 as it made the last pass over the Indian Ocean. Some minutes after the 168 second OMS manoeuvre was completed, the Orbiter plunged into the atmosphere.

Soon *Discovery* appeared in the clear dawn skies over Edwards, looking little the worse for wear. Hartsfield had kept the spacecraft under automatic control for most of the entry but, as soon as the Orbiter went subsonic and began its 251° turn onto final approach, the veteran pilot took the controls himself. He aimed *Discovery* squarely at the centreline of Lakebed Runway 17 and landed the spaceplane in the rays of the rising Sun. The Orbiter's main landing gear wheels first touched the ground at 13:37:54, giving a flight time of 6 days 0 hours 56 minutes and 4 seconds. The nose gear came down smoothly and *Discovery* rolled for just over 3 km before coming to a stop after about 60 seconds.

SATELLITE DIGEST-179

Robert D. Christy
Continued from the December issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

PROGRESS 23 1984-86A, 15193

Launched: 0628*, 14 Aug 1984 from Tyuratam by A-2.
Spacecraft data: Similar in appearance to Soyuz T-12 except for the absence of solar panels.
Mission: To carry scientific and technical equipment, research materials, food, fuel and mail to the long stay crew of Salyut 7. Docked with Salyut's rear port at 0811, 16 Aug; undocked at 1613, 26 Aug and executed a destructive re-entry manoeuvre at 0128, 28 Aug 1984.
Orbit: Initially 186 x 250 km, 88.80 min, 51.60°, then by way of a 210 x 266 km transfer orbit to rendezvous with Salyut at 341 x 369 km, 91.59 min, 51.60°.

COSMOS 1590 1984-87A, 15197

Launched: 0950, 16 Aug 1984 from Plesetsk by A-2.
Spacecraft data: Similar to Cosmos 1582.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package. Recovered after 14 days.
Orbit: 210 x 266 km, 89.33 min, 82.35°.

AMPTE 1 (CCE) 1984-88A, 15199

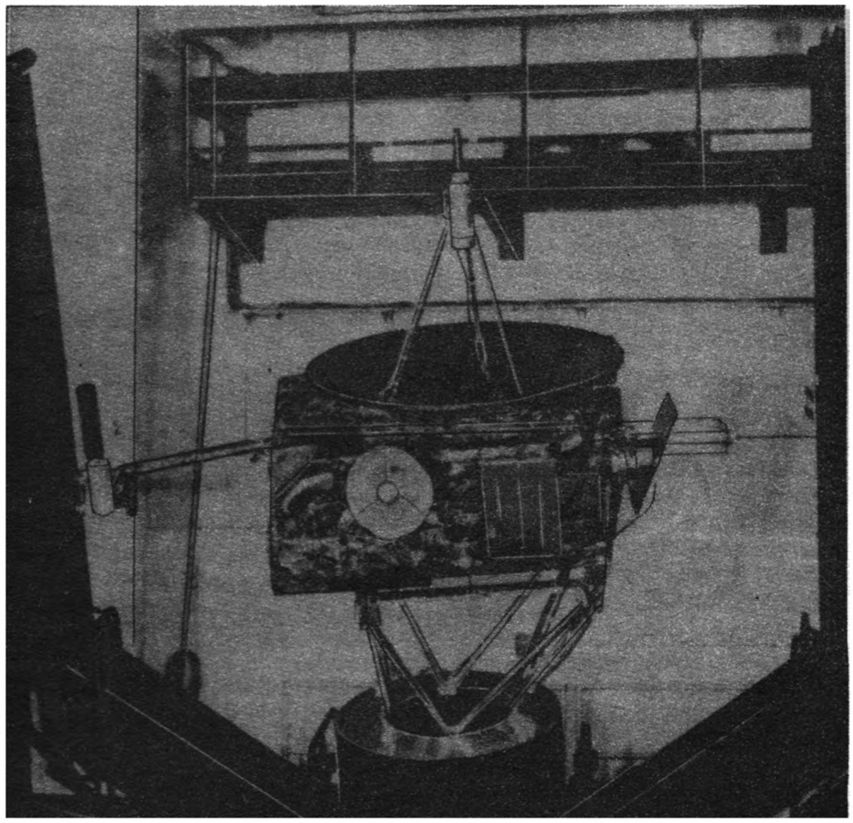
Launched: 1448*, 16 Aug 1984 from Cape Canaveral by Delta 3924.
Spacecraft data: Octagonal prism, approx 2 m diameter and 1 m high and mass 242 kg. Power is provided by a solar array of one panel on alternate sides.
Mission: Part of a three spacecraft mission, this US satellite is also known as the Charge Composition Explorer. Its role is to detect tracers ions released into the magnetosphere by the German IRM satellite. AMPTE stands for Active Magnetospheric Particle Explorers.
Orbit: 1124 x 49925 km, 944.23 min, 4.83°.

AMPTE 2 (IRM) 1984-88B, 15200

Launched: With AMPTE 1.
Spacecraft data: Irregular cylinder, approx 2 m long and 2 m diameter. The mass is 605 kg.
Mission: To release, at intervals, clouds of lithium and barium ions which will interact with the magnetosphere and will be detected by the US and British built satellites. One major event was the formation of an artificial comet in the solar wind, the first performance of such an experiment.
Orbit: 383 x 114570 km, 2657 min, 29°.

AMPTE 3 (UKS) 1984-88C, 15201

Launched: With AMPTE 1.
Spacecraft data: Multi-faced prism, approx 1.5 m diameter, 0.5 m long and mass 77 kg.
Mission: Third AMPTE satellite, flying in formation with IRM and measuring disturbances in the immediate vicinity during the ion cloud release.
Orbit: As IRM.



The European Ulysses (formerly ISPM) solar probe undergoes tests in a solar simulator at Toulouse in France. Launch is set for May 1986.

MOLNIYA-1(62) 1984-89A, 15214

Launched: 0827, 24 Aug 1984 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with conical motor section at one end, deriving power from a 'windmill' of six solar panels. Length 3.4 m, diameter 1.6 m and mass 1800 kg approx.
Mission: Communications satellite providing telephone, telegraph and TV links through the 'Orbita' system.
Orbit: Initially 474 x 40901 km, 738.57 min, 62.74°, then lowered to 718 min to ensure daily ground track repeats.

EKRAN 13 1984-90A, 15219

Launched: 1951, 25 Aug 1984 from Tyuratam by D-1-E.
Spacecraft data: Cylinder with a pair of boom-mounted solar panels and a flat aerial array at one end. Length 5 m, diameter 2 m and mass in orbit around 2000 kg.
Mission: To transmit programmes of Central Television to collective receiving aerials in remote areas of the USSR.
Orbit: Geosynchronous above 99° east longitude.

1984-91A 15226

Launched: 28 Aug 1984, possibly from Vandenberg AFB.
Spacecraft data: Not available.
Mission: Not available.
Orbit: Not available.

COSMOS 1591 1984-92A, 15232

Launched: 1010, 30 Aug 1984 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and a cylindrical, supplementary payload at the forward end. Length 6 m, max diameter 2.4 m and mass around 6000 kg.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package. Recovered after 14 days.
Orbit: 209 x 263 km, 89.28 min, 82.34°.

BOOK NOTICES

Halley's Comet
D. Tattersfield, Basil Blackwell, 108 Cowley Road, Oxford OX4 1JF, 164pp, 1984, £6.50.

This book is bound to be popular. It is written for the layman with no background of scientific knowledge but who will be stimulated by the once-in-a-lifetime reappearance of Halley's comet. It is clear, informative and contains just the sort of information that the ordinary reader will want to know e.g. the comet's history, motion, myths and superstitions and, furthermore, how to photograph it and how to enjoy microcomputer programs such as those also devised by the author to show the comet's path in the sky.

This is a very timely work. It deals with its subject by responding to a series of hypothetical questions, but exactly the sort of questions most people ask, such as as "how bright will it be?, how fast is it moving?" etc.

There are several references to Society publications in its pages though the text appears to have been finalised before publication of the Jan 1984 issue of *JBIS* devoted wholly to Halley's Comet and which contains much additional information.

The New Race for Space
J.E. Oberg, Stackpole Books, P.O. Box 1831, Cameron and Kelker Streets, Harrisburg, Pennsylvania 17105, USA., 1985, 224pp, $14.95.

This book continues the story of the Russian space programme begun by the author in a previous volume and now expanded to include a comparison of the US and USSR programmes, detailing both accomplishments and probable goals.

The author, of course, knows his subject well and many worldy-wise comments come from his lips, for example "the old conflicts about the respective values of manned v unmanned space exploration continue... the same arguments simply recycle themselves every few years..."

On balance, the author predominates in his examination of Soviet space activities, no doubt reflecting genuine American interest in this, but there is much else. For example, a chapter is devoted to advanced-type spaceships in which he mentions not only Daedalus but the anti-matter propulsion issue of *JBIS* which, again, broke new ground.

The book presents a mixture of purely factual accounts of various flights, with an extrapolation into the future to indicate various programmes likely to develop, interspersed with comments on some of the political aspects involved. The result is a most readable volume, fascinating both in what it describes and for the implications for the future. It provides a guide, not for the specialist but for the general reader to show how some aspects of the space drama are unfolding.

Planetary Rings
Ed. R. Greenberg and A. Brahic, University of Arizona Press, 1615 E. Speedway, Tucson, Arizona 85719, U.S.A., 784pp, 1984, $35.00.

Our conception of planetary rings has undergone a revolution in recent years. Saturn's rings have changed from fuzzy ovals to finely detailed structures; the rings of Jupiter and Uranus have progressed from mere hypotheses to well-measured entities, while interpretation of the properties of rings is beginning to produce explanations about the processes that shape or process them - matters that may have ramifications to systems such as galaxies or the nebulae from which planets form.

Strangely, despite the flood of new information, there is very little direct evidence about what rings are, how they are formed or how they behave. Such questions can only be answered by building theoretical models and by comparing these with past and future observations. The subject-matter of this book is thus concerned with presenting a first-generation of such models. To this extent, although particular emphasis is given to observations of the rings of Jupiter, Saturn and Uranus, an extremely large part of the book is concerned with dynamical processes such as dust-magnetospheric reactions, the effects of radiation forces, collisions and the formation of waves.

For many years, Saturn's rings, for example, were regarded either as the uncoagulated remnant of a disc from which later satellites formed, or were fragments of a satellite which approached too close i.e. inside Roche's limit. More than a century later this central issue is still unresolved, though the presence of "shepherd satellites" (i.e. large collision fragments) coexisting in the same orbital range as ring particles appears to favour the latter idea.

Atoms of Silence: An Exploration of Cosmic Evolution
H. Reeves, The MIT Press, 126 Buckingham Palace Rd, London SW1W 9SD, 244pp, 1984, £14.20.

The Universe is a vast and forbidding place, with a plethora of complex phenomena that we do not yet understand. The author, an astrophysicist, takes the reader through the basics of cosmology and how Man might fit into it. He uses the metaphor of music for all the orderliness in the Universe that might have been cosmic "noise" instead.

The book takes a philosophical view of the Universe with a chatty narrative peppered with all the basic facts. It is not a volume to be consulted when in search of hard information but rather one to be enjoyed at leisure to answer the more general questions of why? and what happens next?' It cannot fail to excite the interest of the newcomer.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

DO YOU REMEMBER?

25 Years Ago...
7 January 1960. NASA's first administrator T. Keith Glennan at a meeting with NASA staff agrees that the follow-on programme to Project Mercury should have the objective of manned flight to the Moon. The NASA plan called for manned circumlunar flights for the late 1960's and a lunar landing for some time after 1970.

20 Years Ago...
21 December 1964. The 46 kg Explorer 26 scientific satellite is launched by Delta 27 from Cape Canaveral to study natural and artificial radiation belts around the Earth.

15 Years Ago...
18 December 1969. NASA announces that Launch Complex 34 at KSC is to be used for manned Apollo Applications Programme (Skylab) Saturn 1B launches. However, the following May it was decided that significant cost savings could be made if the launches were made from Launch Complex 39 and the plan to use LC-34 was abandoned.

10 Years Ago...
14 January 1975. Earth Resources Technology Satellite 1 (ERTS-1) is renamed Landsat 1 by NASA. Eight days later Landsat 2 reaches orbit from Vandenberg AFB in California.

5 Years Ago...
24 December 1979. First launch of the ESA Ariane rocket from Kourou, French Guiana. During this successful test flight a 1.6 tonne technological payload was placed into a geostationary transfer orbit.

K.T. WILSON

JBIS

The January 1985 issue of *JBIS* is devoted to 'Soviet Astronautics,' with the following papers:

1. 'The Evolution of the Vostok and Voskhod Programmes,' by R.F. Gibson and P.S. Clark;
2. 'The Soviet G-1-e Manned Lunar Landing Programme Booster,' by C.P. Vick;
3. 'Soviet Spacecraft Masses for Earth Orbital Programmes,' by P.S. Clark;
4. 'Soviet Spacecraft Masses for Deep Space Missions,' by P.S. Clark;
5. 'The Soviet Space Year of 1983,' by P.S. Clark.

Copies of this issue are avaiable at a cost of £2 ($4) post free, from The British Interplanetary Society, 27/29 South Lambeth Rd., London SW8 1SZ. Copies of the October 1983 'Soviet Astronautics' issue are still available at £2 ($4) each.

The December 1984 issue of *JBIS* is devoted to "Space Technology." The following papers are included:

1. "Advanced Space Transportation Requirements and Options" by M.W.J. Bell.
2. "Future Prospects in Space Envisaged by a Forum of European Space Companies" by M. Toussaint.
3. "Commercial Utilisation of Space: New Business Opportunities" by L. Bellagamba and K.H. Robinett.
4. "A Future European Launcher: Ariane 5/Hermes" by J.C. Cretenet and P. Marx.
5. "An Unmanned Platform as an Initial Capability in Space" by T.J. Sheskin.
6. "Satellite Constellations" by J.G. Walker.

This December's issue is available at a cost of £2 ($4) post free from the Society. Earlier "Space Technology" issues still available at a cost of £2 ($4) each are: February 1984, September 1983, July 1982, December 1981 and April 1981.

SURPLUS LIBRARY BOOKS

We have a number of surplus Library Books and Reports on astronomy and space that are being offered at very low prices. To secure a list of those available, simply send a reply-paid envelope with your request to The British Interplanetary Society, 27/29 South Lambeth Rd, London SW8 1SZ. If you spend £20 or more you may deduct a 10% discount.

Please enclose a 20p stamp and specify if you require the Book List, Technical Report List, or both.

DELUXE CERTIFICATES

Both Fellows and Members may now purchase high-quality certificates suitable for framing. These are 29.5 41.5 cm in size, printed in three colours and with the member's name hand-inscribed. They are available for only £5 ($8) post free.

When ordering, please indicate membership grade and allow six weeks for delivery. Provision for ordering these certificates also appears on the 1985 subscription renewal form.

1985 SUBSCRIPTION FEES

There is good news for all members: fees for 1985 will remain unchanged from 1984 in spite of rising costs.

Direct Debit Scheme

Our old Bankers Order System has now been phased out. Direct Debit slips are available from the Executive Secretary but, as these will not now come into operation until 1986, a separate remittance for 1985 must be made.

Amounts payable for the calendar year January-December 1985 are as follows:

RATES

Members	Sterling	US Dollars
Under the age of 18 years	£16.00	$26.00
Between 18 and 20	£18.00	$30.00
21 years of age and over	£21.00	$36.00
Fellows	£23.00	$40.00

Age Allowance

A reduction of £4.00 ($6.00) is allowed to members of every grade over the age of 65 years on 1 January 1985.

JBIS and *Space Education*

The additional subscription payable for *JBIS*, where required as well as *Spaceflight*, is £20.00 ($34.00). For *Space Education*, it is £4.00 ($6.00).

Methods of Payment

Europe

(a) Please pay in sterling with a cheque which shows a UK address, where it can be paid.

(b) Cheques drawn in sterling payable at a bank in Europe must include £2.00 to defray charges and collection costs. Eurocheques have no charges *only* if the account number is written on the back.

(c) Banks which remit directly to the Society must be told to see that the sum is transmitted *free of deductions*.

(d) Remittances from Europe are best made by GIRO. Our GIRO account number is 53 330 4008.

USA and CANADA

(a) US dollar cheques can be drawn on a Bank which gives an address in the United States or in the UK. US dollar cheques drawn elsewhere need to be increased by $8.00 to cover collection charges.

(b) US dollar notes are accepted.

(c) US or Canadian money orders can only be accepted if *expressed in Sterling*. Internal money orders from these countries i.e. those expressed payable in dollars will be returned as they cannot be cashed in the UK.

(d) Canadian bank remittances may easily be made in sterling drawn on their UK agents. If payment is made in Canadian dollars the current exchange rate may be used, plus the addition of 8 Canadian dollars to cover exchange and collection charges.

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Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01–735 3160.

NOTICES OF MEETINGS

Film Show
Theme: **MOMENTS IN HISTORY (PART 2)**

The second of two meetings devoted to historical space films will be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **6 February 1985,** 7.00-8.30 p.m.

The programme will include the following:

(a) A Man's Reach Should Exceed his Grasp

(b) Small Steps, Giant Strides

(c) A Moment in History

(d) Blue Planet

(e) Meteosat

Admission is by ticket only. Members wishing to attend should apply in good time, enclosing a stamped address envelope.

Lecture
Theme: **COMMERCIAL LAUNCH VEHICLES**
By G.M. Webb

The context in which Europe will be competing commercially using its post-Ariane 4 series of launcher will probably be very different from the present situation; the viability of the various options open in the mid-1990's will be discussed.

To be held in the Socity's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **20 February 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Symposium
Theme: **EUROPE-US SPACE ACTIVITIES**

The **1985 Goddard Memorial Symposium,** in conjunction with the **19th European Space Symposium,** will be held at the NASA Goddard Space Flight Center, Maryland, USA on **28-29 March 1985** organised by the American Astronautical Society and co-sponsored by The British Interplanetary Society in association with other Societies.

Offers of papers are invited. Futher information is available from the Executive Secretary and registration forms will be available in due course.

One-day Symposium
Theme: **SPACE STATIONS**

A one-day symposium on the obove theme, considering the technology and applications of Space Stations, will be held in the Society's Conference Room on **17 April 1985.**

Offers of papers are invited. Potential authors are requested **to contact the Executive Secretary, at 27/29 South Lambeth Road, London SW8 1SZ.**

Lecture
Theme: **COHERENT LIGHT FROM SUPERNOVAE**
By A.T. Lawton
President of the Society

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **15 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture
Title: **SATELLITE INSURANCE**
By R Buckland

Launching satellites into space is a risky business. No commercial project can go ahead without insurance to cover launch and other risks. This talk will describe the role that satellite insurance plays in the development of commercial activity in space.

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **12 June 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time, enclosing a stamped addressed envelope.

36th IAF Congress

The 36th Congress of the International Astronautical Federation will be held in Stockholm, Sweden on **7-11 October 1985.**

Members of the Society wishing to present papers are asked to notify Dr. L.R. Shepherd, Chairman of the BIS International Liaison Committee at Society HQ as soon as possible. Members wishing to present papers to the IAF Student Conference must submit them through the Society.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:

6 Feb 1985
20 Feb 1985
1 May 1985
15 May 1985
12 Jun 1985

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

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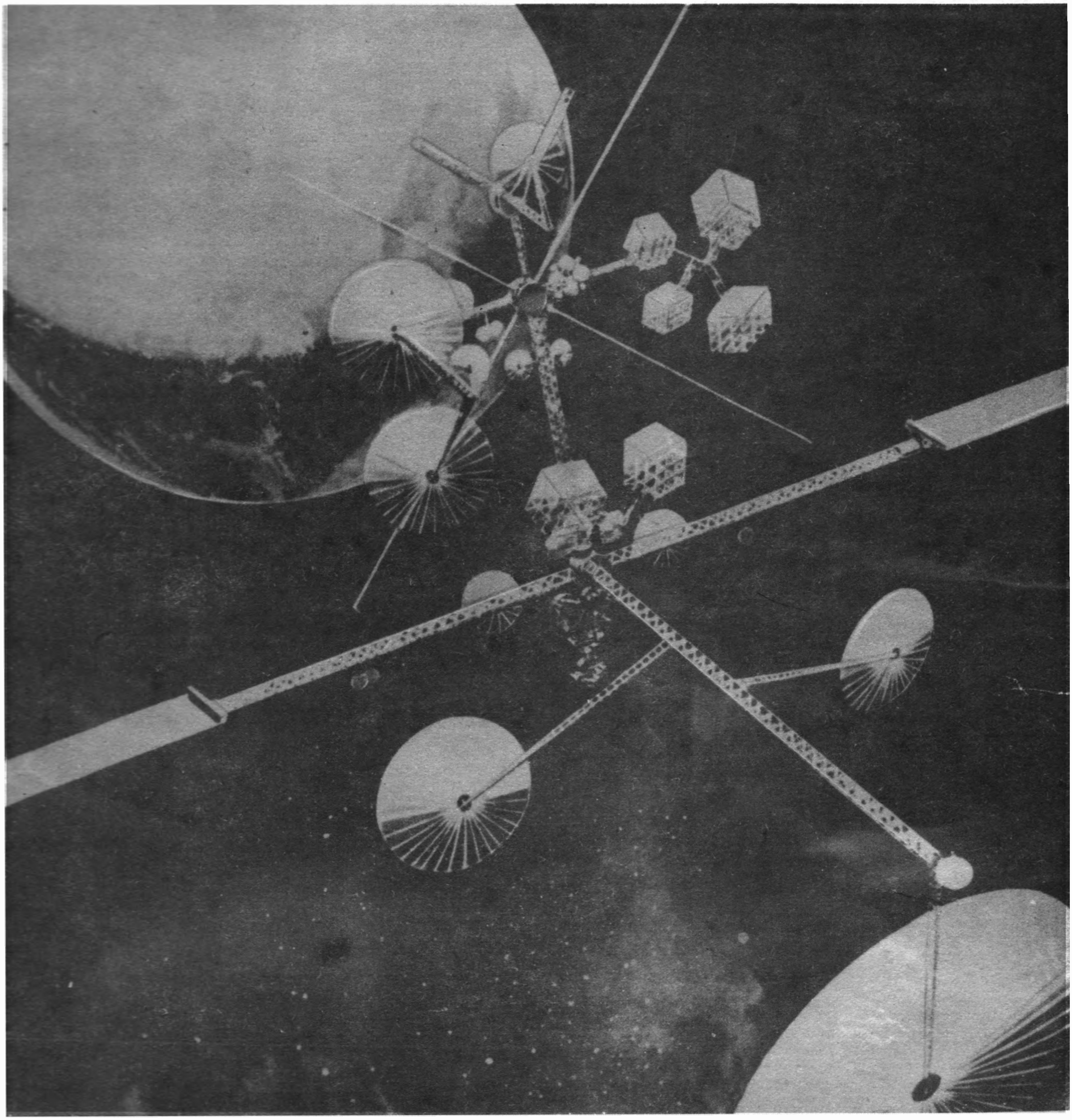
spaceflight

88905 КОСМИЧЕСКИЕ ПОЛЁТЫ № Т-2—
(спейсфлайт)
По подписке 1985 г.



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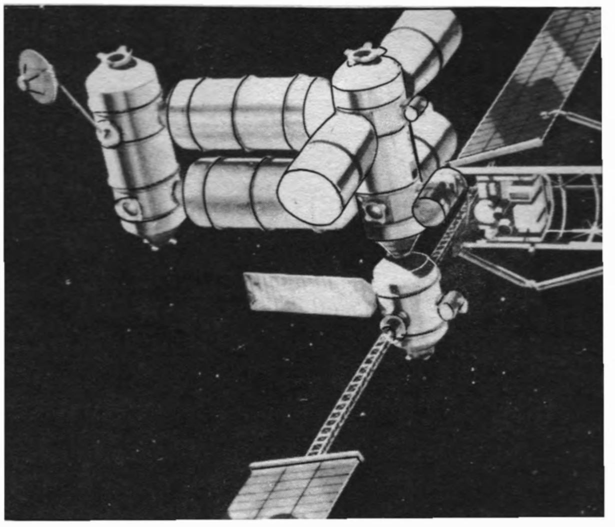
FEBRUARY 1985
VOLUME 27 NO. 2

SPACE STATION PLANS

The US Space Station is the next major manned space project of the western world, with initial operations in orbit expected in the early 1990's. Plans for participation are being considered by most European countries, including the UK. Our Society, which has long advocated permanent manned bases in space, will contribute further to the discussions by providing updated reviews at a one-day symposium. The date is 17 April 1985, the venue HQ. A provisional list of papers to be presented by a panel of international speakers will include the following:

1. **'European Space Station Overview,' by F. Longhurst (ESA).**
2. **'Space Station Platform - Overview,' by Dr. R.C. Parkinson (BAe).**
3. **'User Requirements for Space Stations,' by I. Franklin (BAe).**
4. **'Space Station Pressure Compartment,' by Prof. Valleriani (Aeritalia).**
5. **'Application of Propulsion Modules to Space Station Infrastructure,' by D. Gilmour (BAe).**
6. **'Orbital Replacement Units for Space Stations,' (Provisional).**
7. **'Assembly and Maintenance of Space Stations,' (Provisional).**



8. **'European Overview of the Space Station Proposals,' by R. Gibson.**

The Symposium will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, England on 17 April, 9.30 a.m. to 5.30 p.m. The registration fee is £15 (non-members £17). Forms are now available from the Executive Secretary at the above address. The places remaining are limited so early application is advised.

1985 SUBSCRIPTION FEES

There is good news for all members: fees for 1985 will remain unchanged from 1984 in spite of rising costs.

Direct Debit Scheme

Our old Bankers Order system has been phased out. Direct Debit slips are now available from the Executive Secretary but, since they will not come into operation until 1986, a separate remittance for 1985 will have to be made.

Amounts payable for the calendar year January-December 1985 are as follows·

RATES

Members	Sterling	US Dollars
Under the age of 18 years	£16.00	$26.00
Between 18 and 20	£18 00	$30.00
21 years of age and over	£21.00	$36.00
Fellows	£23 00	$40.00

Age Allowance

A reduction of £4.00 ($6.00) is allowed to members of every grade over the age of 65 years on 1 January 1985.

JBIS and *Space Education*

The additional subscription payable for *JBIS*, where required as well as *Spaceflight*, is £20.00 ($34.00). For *Space Education*, it is £4.00 ($6.00).

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(a) Please pay in sterling with a cheque which shows a UK address, where it can be paid.

(b) Cheques drawn in sterling payable at a bank in Europe must include £2.00 to defray charges and collection costs. Eurocheques have no charges *only* if the account number is written on the back.

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spaceflight

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CONTENTS

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WHERE OH WHERE HAVE THE MEDIA GONE?

The 35th IAF (Lausanne) Congress produced no less than 500 papers ranging over the whole spectrum of astronautics. Its main theme, 'Space for the Benefit of all Nations,' was hardly a mundane topic. Astronauts, cosmonauts and leading space figures jostled in the assemblies. All were discussing major developments in the history of mankind *yet representation by the media was almost totally lacking!*

The Department of Trade and Industry conference last October was concerned with, no less, the nature and extent of UK participation in the American Space Station proposals. There was hardly a more apt subject for discussion, yet representation by the media was *barely a handful.* Our Space '84 event had the interesting theme of 'Space - The Future of Mankind.' Surely, the UK media would have turned up in force for *this,* on their own doorstep. Not so.

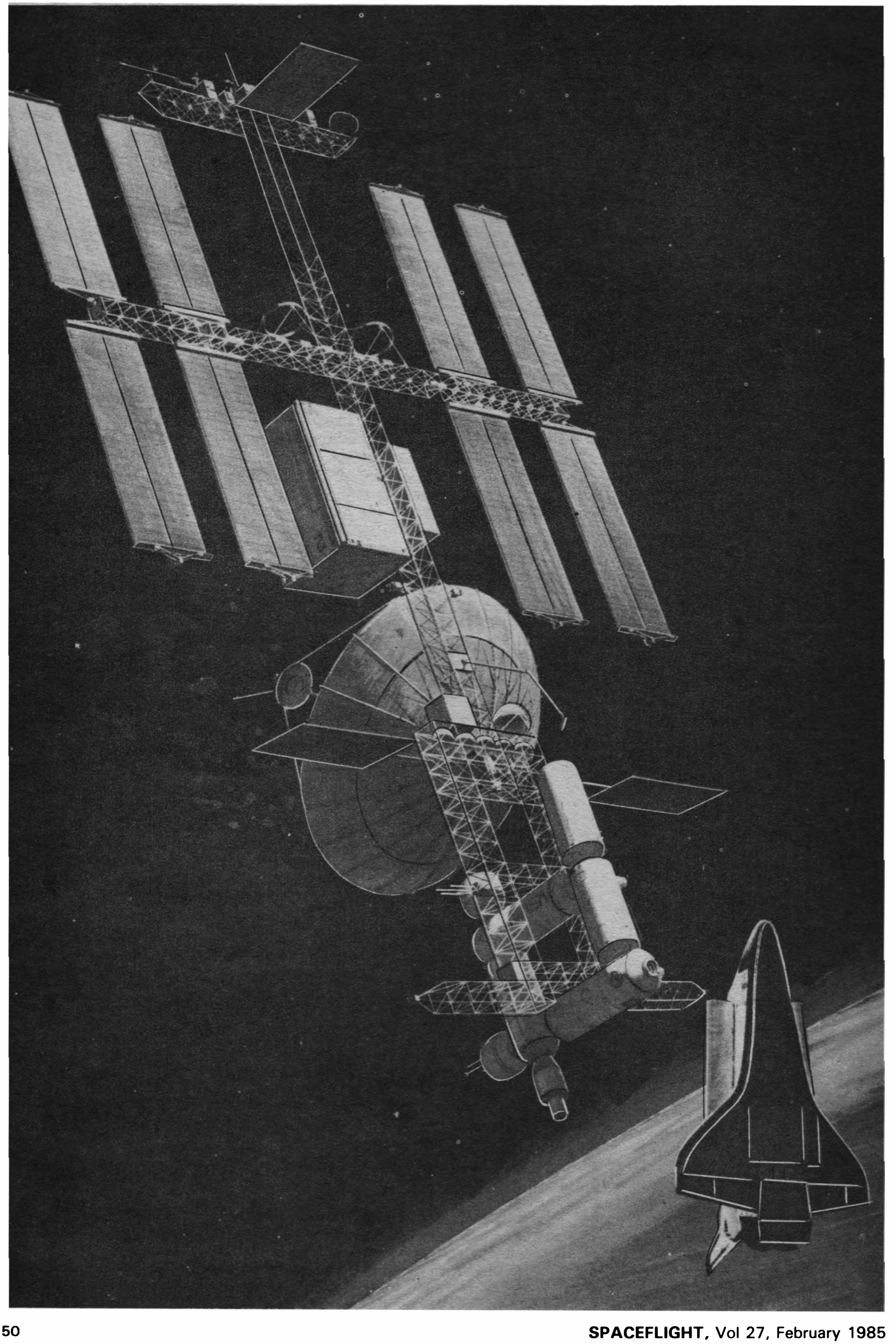
So we have the problem why, apart from a few notable exceptions, is the media coverage so slight? A sight of any newspaper any day will disclose what the media regard as important. Radio and TV coverage is similar. We receive a constant stream of letters pointing out that even spectacular 'Visuals' such as a Shuttle launch are covered in a most superficial manner. Today, among the media, it is the specialised magazines that carry the main torch in presenting to most of us information on these matters of major importance, but they are geared to reach only a few and certainly not the Great British Public.

The media respond that the lack of coverage is owing to the lack of public interest, but the reverse could equally be true - for everyone knows that great intense public interest can be aroused by media coverage. So is it the fault of the newspapers or their reporters, or the Great British Public itself? If the latter, how does one explain the enormous crowds thronging every road to witness the arrival of the Shuttle *Enterprise* (even though only a development model!) at Stansted Airport in 1983? When it comes to the 'presentation' of radio and TV does the public slide away because they instinctively recognise the difference between our plague of 'instant pundits' and the real thing?

Formerly, UK press coverage of space events was extensive and well-informed but few of the press corps who once so faithfully discharged this task are still with us. Wherever the fault lies, it is the result that now worries us, for whole generations are growing up without adequate information or instruction on space - one of the most significant of the major new developments of our time.

COVER

Individual communications satellites might be replaced one day by large antennae 'farms' in geostationary orbit. They could help to prevent congestion of the geostationary arc and the large antennae would facilitate frequency re-use to allow more communications traffic. These platforms would be serviced by remotely-controlled vehicles and would permit payload growth and updating. *NASA*



THE SPACE STATION: THE GREAT DEBATE

By Roy Gibson

This background paper was presented at a meeting organised by the Dept. of Trade and Industry, attended by the Society's President and Executive Secretary. It provides an up-to-date picture of the Space Station situation in the United States, Europe and, more briefly, in Japan and Canada.

NASA Space Station Programme

President Reagan announced on 25 January 1984 that he was instructing NASA to develop a permanent, manned orbiting space station within a decade. He subsequently invited the Heads of Government of the UK, France, FRG, Italy, Japan and Canada to participate in the project and NASA officials have contacted West European states bilaterally and through the European Space Agency (ESA). NASA sees it as the next logical step in the beneficial exploitation of space. They also regard it as a symbol of the linkage between the western democracies and an opportunity to display international cooperation in high technology.

The space station will be assembled in orbit from Shuttle-launched modules and comprise laboratories (both within and outside a shirtsleeve environment), living quarters, a logistics module (for supplies, particularly propellants) and a resource module (to provide power, thermal, propulsion and communications functions). It will orbit at 28.5° inclination to the equator and have 75 kW power. The basic project also includes at least one co-orbiting platform, a polar orbiting platform serviced from the Shuttle, internally and externally attached payloads, arrangements for servicing satellites and orbital manoeuvring vehicles and arrangements for assembly of payloads and large structures.

By the year 2000, NASA envisage a complex costing $20,000 million, but their proposal for the initial programme described above is $8,000 million (1982 prices) not including launch, utilisation or operation costs. The NASA Administrator has suggested that a European contribution should amount to 20-25% of NASA's investment i.e. up to $2,000M over eight years, while Canada and Japan should each contribute 10%. These contributions would be additional to the American $8,000 million and so enhance the programme beyond what the US can immediately afford.

Initial uses of a manned station fall into four classes:

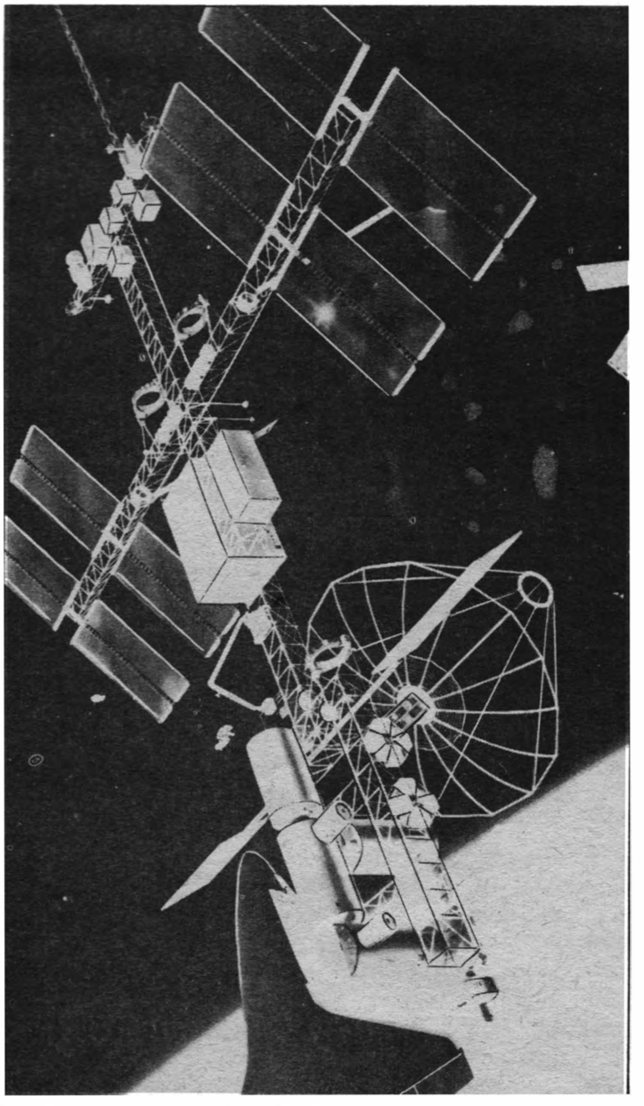
i. those that would exploit the microgravity and vacuum environment for experimental or commercial purposes;

ii. those that would utilise the station or a co-orbiting platform as a permanent satellite;

iii. those that would use the station to test technologies designed for incorporation in other satellites; and

iv. those that would use the station to refurbish and maintain satellites or to undertake check-out and/or final assembly for satellites before they are boosted to their final orbits.

The first encompasses space processing and life sciences. It is impossible to recreate on Earth for any length of time the low gravity environment achieved in orbit. Space could become an important resource for the ultrahigh purification of drugs or production of high value crystals and metal alloys and, whereas the Shuttle and Spacelab can sustain these conditions for several days, a station will do so for months or years.



NASA's 'power tower' Space Station concept.

For remote sensing, the polar-orbiting platform planned as part of the core manned space station could have a far reaching impact.

After several years of in-house NASA study and some external support contracts, the Space Station has been formally approved and an amount of US $155M earmarked from the NASA budget in FY84. A 250 man team, drawn from all NASA establishments, produced on 20 August 1984, a draft Request For Proposal (RFP) for the Space Definition and Preliminary Design. After three weeks for commments both from US industry and from potential international participants, the definitive RFP was issued to industry on 14 September 1984.

For the first time in a NASA programme since Apollo, there will be no industrial prime contractor; this function will be fulfilled by Johnson Space Center. The RFP is thus for four separate work packages, for each of which two contractors will be chosen to work in parallel, each supervised by a NASA centre. The content and approximate value of the contracts is summarised in Table 1.

Contractors are instructed to develop a configuration that would meet estimated needs around the year 2010

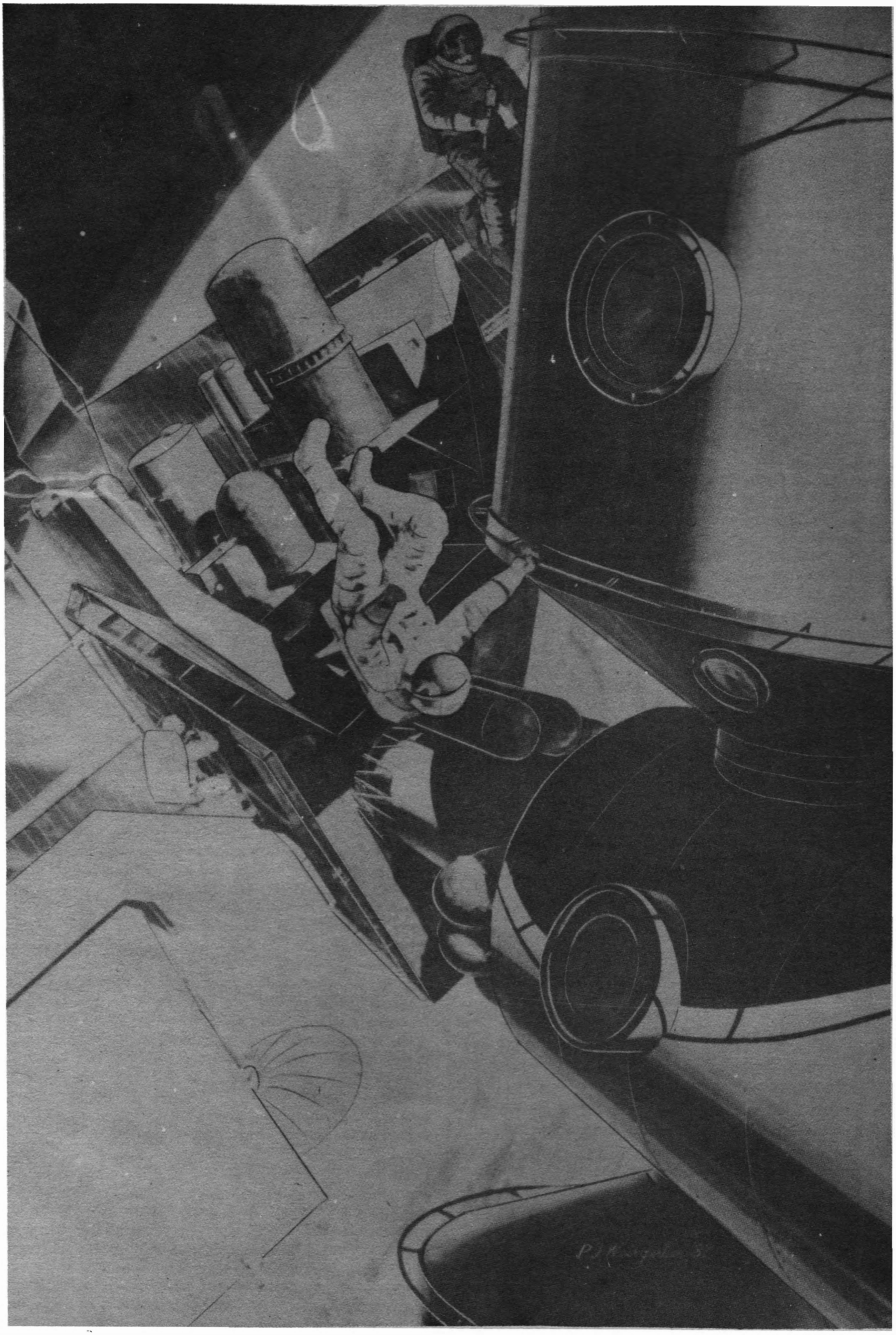
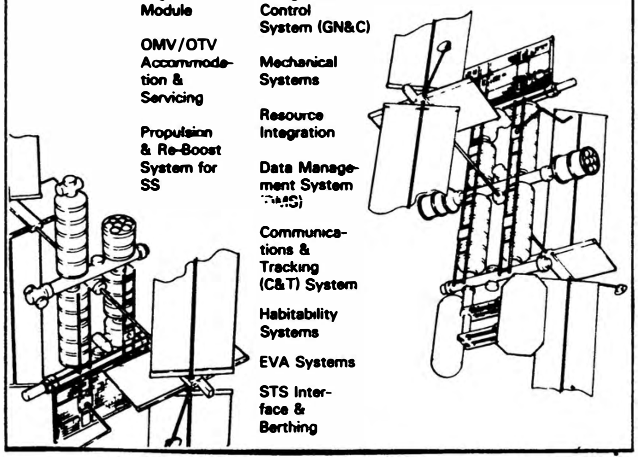


Table 1

	Work Package 01	02	03	04
Supervising Centre	Marshall Space Flight Center (MSC)	Johnson Space Flight Center (JSC)	Goddard Space Flight Center (GSPC)	Lewis Research Center (LeRc)
Approx Value per Contract	25.85 M $	29.95 M $	10.35 M $	6.25 M $
Principal Contents	Common Module	Assembly Trusses Structures	One Laboratory Module Outfitting	Power Generation Sub-System
	Environmental Control & Life Support System (ECLSS)	Connect/Inter-Connect of Modules	Platforms	Energy Storage Sub-System
			Customer Servicing	Power Management & Conditioning Sub-System
	One Laboratory Module Outfitting	Airlock	Attached Payload Accommodations	
		Heat Rejection & Transport		
	Logistics Module	Guidance Navigation & Control System (GN&C)		
	OMV/OTV Accommodation & Servicing	Mechanical Systems		
	Propulsion & Re-Boost System for SS	Resource Integration		
		Data Management System (DMS)		
		Communications & Tracking (C&T) System		
		Habitability Systems		
		EVA Systems		
		STS Interface & Berthing		



and then scale down to an initial Operating Configuration (IOC) that could be operational in the early 1990's within the approved budget envelope of US $8,000 million. In this way NASA hopes to arrive at a configuration capable of considerable expansion without major design changes.

As a reference configuration for the manned core, NASA has given a gravity gradient stabilised concept which has come to be known as the "Power Tower." This has been driven mainly by pointing requirements and power needs. The main characteristics are summarised in Table 2, together with the postulated growth potential.

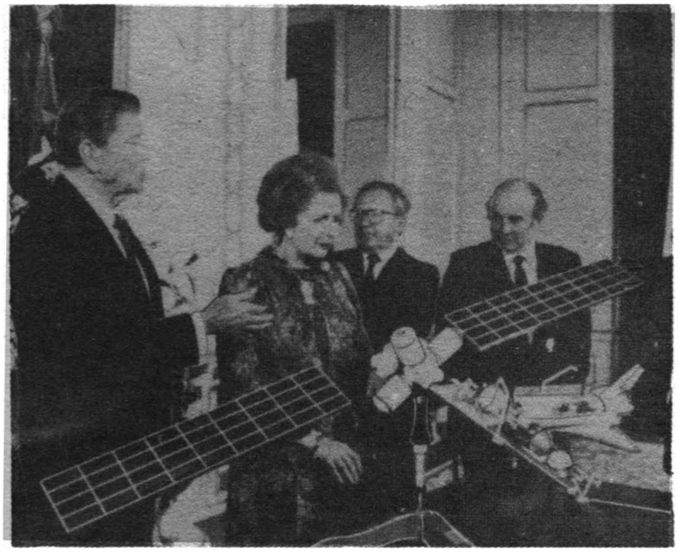
The Space Station will comprise various Space Station Programme Elements (SSEP's) as described below.

Modules

Marshall Space Flight Center, under Works Package 01, is responsible for the definition of a common module

Table 2

	IOC	Growth Potential
Altitude	270 N.Mi	270 N.Mi
Inclination	28.5°	28.5°
Average Power	75 kW	300 kW
Crew	6	18
Number of Pressurised Modules	5	10



President Reagan and Mrs. Thatcher study a Space Station model during the June 1984 economic summit in London.

which - so long as this proves practicable - is to be the basis for all modules developed by NASA. In the initial configuration it is proposed to provide.

- a logistics module
- a living quarters module, and
- two laboratory modules.

Platforms

The original intention was to include possibly only one co-orbiting platform in the initial orbiting configuration but the need for a polar-orbiting platform is being hotly canvassed by potential users and NASA has now had the benefit both of internal studies (particularly by Goddard Space Flight Center and the Jet Propulsion Laboratory) and the recent meetings with scientific and other users. The RFP therefore contains a great deal of flexibility and the call is for a single, multi-purpose platform capable of modular growth and allowing in-orbit interchange of instruments or the processing of module payloads at a standardised interface.

If the money stretches to it, NASA would wish to include, initially, two polar-orbiting platforms (where there is more call for accommodating several instruments on the same platform) and a modular family of co-orbiting platforms. Goddard Space Flight Center appears to favour six to eight small platforms each supplying 5 kW of power.

OTV and OMV

The Orbital Transfer Vehicle (OTV) does not form part of the Space Station, only its accommodation and interfacing. The development of the OTV itself is the responsibility of Marshall Space Flight Center and parallel study contracts have been awarded to Martin Marietta Aerospace and Boeing Aerospace. The Orbital Maneuvering Vehicle (OMV) is, similarly, a separate development, also under the responsibility of Marshall Space Flight Center. The status of these vehicles with regard to international co-operation is unclear but they are not thought to be included in the present invitation.

Congress Approval

It is important to note the conditions imposed by Congress when the Space Station FY84 budget was approved. The commitment of the $155.5M was blocked until 1 April 1985 and its release is subject to NASA

giving satisfaction on two issues:

i. NASA is required to study an option under which the Space Station would initially be man-tended with the permanent manning being phased in at a later date. NASA is under an obligation to spend 10-15% of the definition funds in having this trade-off study made; and

ii. a Space Station Advanced Technology Committee is to be established to identify systems that would advance the technologies of robotics and automation of use, not only in the Space Station but also in ground-based industries. A programme equal to 10% of development costs is to be defined.

NASA has responded promptly to both these requirements. The SSP Phase B contractors are instructed to undertake a meaningful study of the man-tended option and in-house work is also planned in this area. To meet the second point, the California Space Institute (CSI) will lead a university/industry team to guide a comparative effort on systems design and systems technology. The Stanford Research Institute (SRI) will perform technology evaluation and forecasting, and some aerospace companies are to examine the design implications of the Stanford analysis. To pull the work together and to assist NASA in formulating an automation/robotics programme, a high-level advisory and oversight group has been appointed, chaired by Dr. Frosch, the former NASA Administrator.

NASA was due to present to Congress by 15 December 1984 a report on Space Station "Management plans and acquisition strategies."

US Invitation for International Participation

The invitation was first made in President Reagan's last State of the Union message when he invited America's friends and allies to participate, explaining that this participation could range from use of the completed facility to cooperation in the development of the Space Station. In order to underline the political nature of the invitation, Mr. Beggs, Administrator of NASA, was sent to Europe in April 1984 as the US President's personal representative to encourage European countries to respond positively. The subject figured on the agenda of the June 1984 Economic Summit Meeting and the communique provided for a report to the next Summit in 1985.

The draft RFP to industry also addresses this aspects and speaks of an invitation to international friends to become 'builders, users and operators' of the Space Station, warning US contractors that work package allocation could very well be altered as a result of international participation.

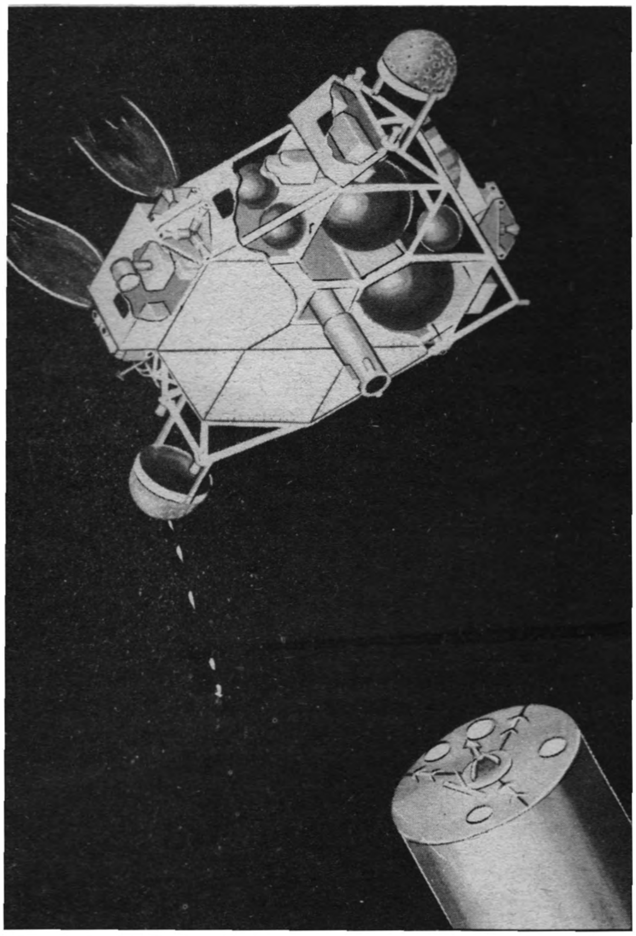
NASA indicated that a reply in principle was being looked for from international participants by the end of 1984 and that they would like all formalities to have been concluded by the end of 1985, i.e. at the time the Space Station configuration is frozen.

The Canadians have indicated to NASA that they are, in principle, interested in participating in the Space Station and that they are presently concluding national studies

NASA Timetable

The key milestones announced by NASA for the SSP are:

Distribution of RFP to industry:	- 14 September 1984
Receipt of industrial proposals:	- November 1984
Selection of contractors and authority to proceed:	- 1 April 1985
Fixing of final configuration:	- October/December 1985
Evaluation of development proposals:	- September 1986-March 1987
Start Phase C/D:	- April 1987



An initial concept for an OMV. *NASA*

to define the nature and extent of this participation. Canada has also informed the European Space Agency (ESA) that Canadian cooperation in the Programme through the Agency is not excluded. A further development of the Remote Manipulator System (RMS) developed for use with the Shuttle is certain to be one, and perhaps the main, Canadian proposal.

The Japanese industry has, from the start, been enthusiastic about participating in the Programme. Four industrial consortia have been formed and internal studies are being carried out, in some cases in association with US firms. The draft proposals are far-ranging and are estimated to cost around US $1,300 million. The Japanese governmental position has not yet been announced but it is known that the Diet will be asked in April 1985 to approve the necessary funding.

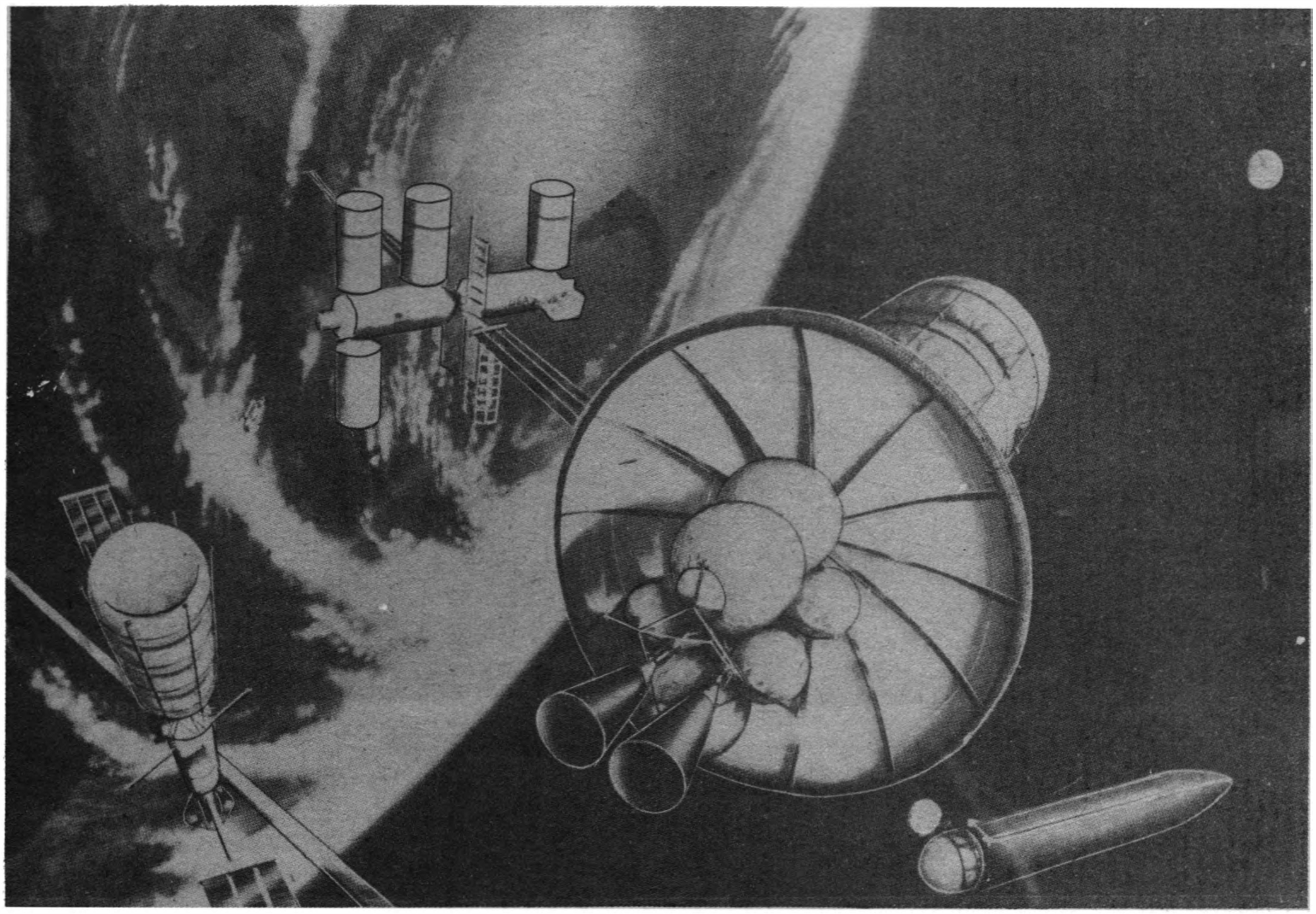
NASA invited potential international participants to attend a workshop in Washington on 20/21 September at which the latest state of the US Programme was described and foreign participants encouraged to discuss the form their contribution might take.

Spacelab Follow-on Programme

Eight ESA Member States agreed to participate in an optional programme, 'Eureca,' at a cost of 155.9MAU. This is a reusable autonomous carrier designed to be launched into space, operated in a free-flying mode for up to six months and retrieved by the Space Shuttle. The first flight is due for mid-1987. The reference orbit is 500 km altitude and an inclination of 28.5°.

European Space Station Programme

In January 1983, nine ESA Member States agreed to contribute to a 13M Accounting Unit 'Space Transporta-



The Space Station could eventually operate as a base for lunar operations. *NASA*

tion Systems (STS) Long-term Preparatory Programme' (LTPP). The object of the programme was to analyse options open to Europe for STS activities beyond Ariane 4 and Spacelab Follow-on Development (FOD) and to prepare decisions on a long-term policy and on the start of new programmes by 1985-86 within the following three areas:

Theme 1 : Future European Launcher.

Theme 2 : European Space In-Orbit Infrastructure (IOI).

Theme 3 : Manned Space Station and continued cooperation with United States.

The United Kingdom contributed to the preparatory plan at the rate of 4%, the average of its share in previous ESA Ariane/Spacelab programmes.

The existence of the plan enabled ESA to reach an agreement with NASA whereby the two agencies keep each other informed on the progress of their studies and permits the participation of US and European industry in all relevant inter-agency conferences.

The ESA Council, meeting in June 1984, agreed on two enabling resolutions approving the execution of two new optional programmes; this means the Agency can examine relevant details and make proposals to the Member States who, before work can start, must formally agree the technical details and funding of these programmes. The new programmes are:

- for the development of the large cryogenic engines (HM60); and for
- a 'space station related programme based on the proposal by the German and Italian delegations...; this programme will be defined with a view to ensure progressively the European autonomy in the field of the manned space station mutually compatible with the future European launching systems.'

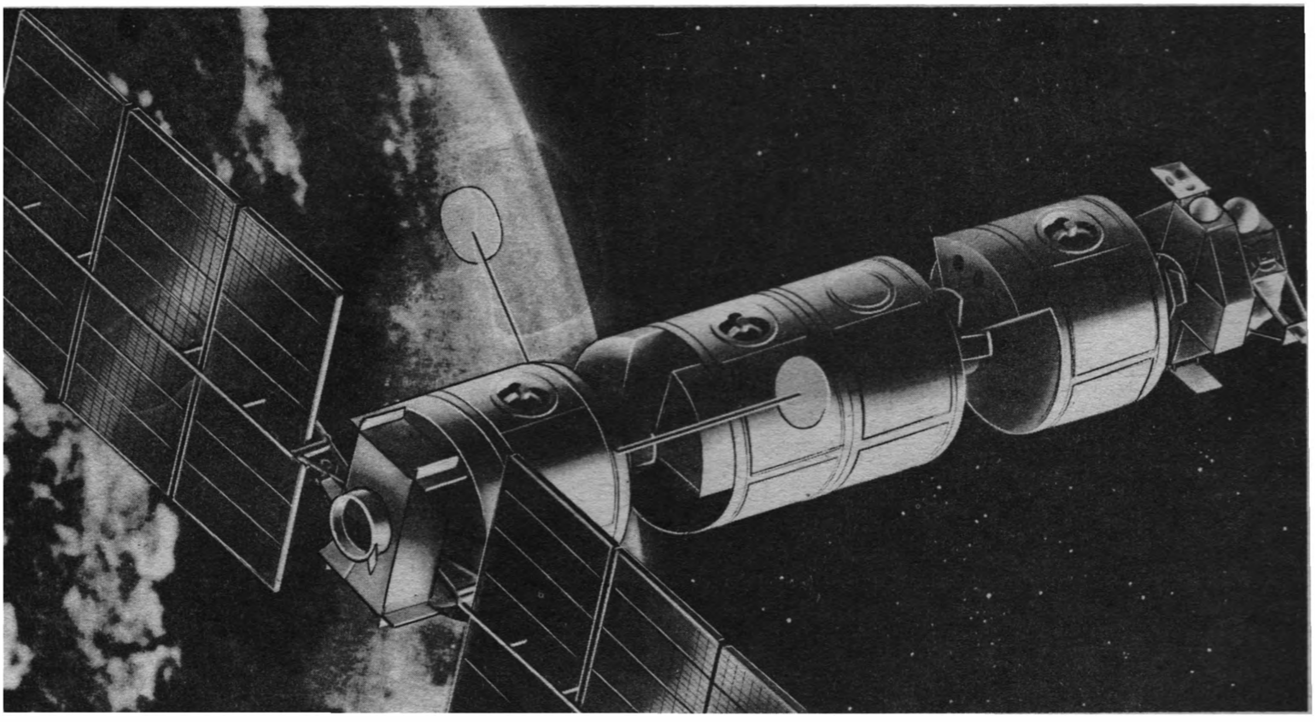
The second Resolution also approved 'in the process of this preparatory programme the consideration of the invitation received from the President of the US...'

The Space Station Resolution envisages a funding of 80 MAU (35 MAU for definition contracts and 45 MAU for a supporting technology programme). For the Space Station Phase B study, ESA hopes to have all the formalities completed in time to allow industry to start work in April 1985 (the same date as for the NASA Phase start).

Meanwhile 1.1 MAU of the Long Term Preparatory Programme will be used to provide two bridging contracts which will be awarded to MBB/ERNO and Aeritalia with instructions to arrange a 'reasonable' geographical distribution of the work. The time before April 1985 is intended to be spent mainly on refining cost analysis, examining maintenance and operations costs and attempting to define the elements in NASA's Space Station Programme available for international participation. The first meeting of the potential participants was arranged for 18 September 1984.

Columbus Programme

The German/Italian proposal referred to in the ESA Space Station Resolution is the so-called Columbus programme. It is funded by the German BMFT (the Ministry of Research and Technology) and the Italian MRST (the Ministry of Scientific and Technological Research) as 'a joint effort for the continuation of European space activities based on the exploitation of Spacelab and Eureca



Columbus envisaged as a free-flyer. *Aeritalia*

technologies and results obtained.' The industrial studies were carried out from April 1983 to July 1984 by MBB/ERNO and Aeritalia, supervised by DFVLR (the German aeronautical and space agency) and the Italian CNR (national research agency and location of the Italian National Space Plan). The studies also took account of considerable in-house DFVLR work which had been done under the name of Orbitas.

As presented to the ESA Council in June 1984, for 'Europeanisation,' the Columbus programme consists of:

i. Pressurised modules (PM), a further development of Spacelab, and intended to be either manned or man-tended;

ii. Payload carriers (PC), a further development of European hardware designed to carry experiments, material production facilities etc; and

iii. Resource Module (RM) providing power, communications, data management and other housekeeping facilities for the PM and PC.

The programme also provides for payloads, ground segment and some demonstration missions in orbit due to commence around 1993. The launching of this initial configuration would depend on the US Shuttle, but Ariane 'could be considered as an option for manned launches.' The programme is intended to be 'compatible' with the NASA Space Station 'as a general policy,' and the pressurised module is seen as being initially attached to and serviced by the Space Station. A prominent feature of the programme is the possibility of the Columbus elements separating from the US Space Station and constituting an independent system serviced by European launches.

The initial programme described above is estimated by the German and Italian delegations as costing 1750 MAU (some additional internal man-power costs would be furnished free by these two Member States in return for a dominant role in the management of the programme). The German delegation has indicated its willingness to fund up to 50% of the programme and Italy appears anxious to provide 25%.

The presentation of the programme to the ESA Council also described an uncosted extension programme which includes further development of the PM to enable it to operate as a man-tended free-flyer and a servicing vehicle providing capability for orbital manoeuvring and crew transfer between the US Space Station or Shuttle and the 'European free-flying system.'

COLUMBUS: SYSTEM CONCEPT AND CONSTITUENTS

Resources Module (RM)

- Provides attitude and orbit control, power supply, heat rejection, TT & C and information management to payload carriers and pressurised module when free-flying.
- Two sizes of RM's envisaged based on mission requirements. Major difference in heat rejection and power supply capability.
- Supports all orbit and attitude requirements of platforms and PM.
- Limited orbit transfer capability.

Platform

- Consists of a modular payload carrier with subcarriers for the payload complements and a resources module.
- Operates at 28° inclination and polar orbits over wide range of altitudes.
- Supports payloads of all identified types with power levels up to 17.5 kW (except those requiring pressurised environment).
- Payload exchange possible on subcarrier or orbit replaceable unit level.

Concept based on Columbus specific requirements and on external requirements stemming from payloads, SS of STS.

Pressurised Module

- Three segment SL-derived module.
- Provides pressurised environment for experiments and crew.
- To operate attached to the Space Station or free flying with resources module (co-orbiting with Space Station).
- Permanently manned for attached operation, man-tended when free flying.

UK SPACE STATION PARTICIPATION: 20 Key Questions

Posed by Dr. David J. Stanley (Logica UK Ltd)

The building of the Space Station and UK involvement have to be firmly justified because of the considerable investment involved. Dr. Stanley considers 20 points of importance.

The Political Dimension

1. What are the justifications for significant new UK investment?
2. How can we harmonise UK/European/US priorities?
3. Who are our most natural partners?
4. What is the role of defence interests, if any?

The Economic Dimension

5. Is the primary benefit to users or developers?
6. Which application areas will eventually generate revenue?
7. Will it make scientific research more cost effective?
8. What is the pay back time?

The Technological Dimension

9. How can we use SS to extend classical space engineering?
10. How does it relate to other UK investments in advanced technology?
11. Will it be a driving force for Information Technology?
12. Is the UK vulnerable to foreign monopoly of expertise/facilities?

The Management Dimension

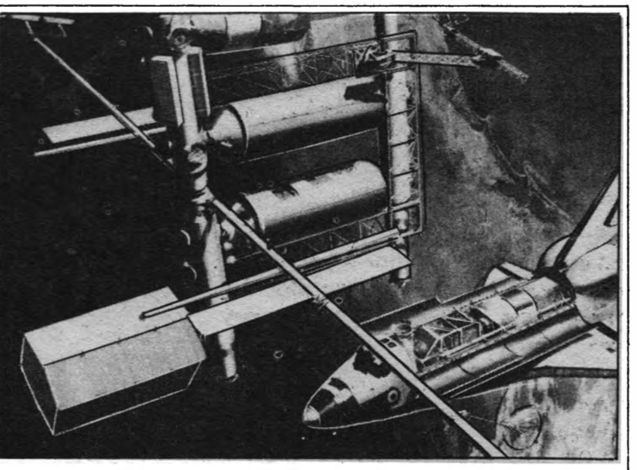
13. Should the UK seek a prime role or concentrate on technology?
14. How do we maintain a direct interface to SS?
15. Can we guarantee total system visibility and access?
16. How do we protect our interests in the exploitation phase?

The Pragmatic Dimension

17. Can the UK get its act together quickly enough?
18. Can Europe get its act together quickly enough?
19. Will the US significantly modify its conditions for participation?
20. How much flexibility should we maintain?

Some Personal Answers

1. To regain our position among the leaders of space exploitation at reasonable cost and risk, with the prospect of providing direct access through UK astronauts.
2. By supporting a truly European response consistent with valid UK interests.
3. A balanced group of ESA member states with an equitable management structure among the industrial contractors.
4. They must be integrated into an overall national strategy for participation with due regard for the constraints imposed by the policies of our partners.
5. The main justification must depend on the advan-



tages offered by SS to users but the technological benefits to the aerospace industry provide an important shorter term payback.
6. It is almost certainly premature to say, except that most organisations who have seriously looked at the options have identified commercial potential.
7. A range of existing platform options will almost certainly mean that a higher proportion of the space science budget can be devoted to payloads.
8. Long; certainly not before the 21st century. We are investing in the future of our children and grandchildren.
9. Concentrate on activities related to manned missions.
10. Harmonisation should be sought especially with the Alvey Programme. I propose the establishment of a technical synergy unit.
11. Emphatically yes. In particular it will place challenging demands on distributed software engineering, artificial intelligence and man-machine interaction.
12. Perhaps in some areas of specialised manufacturing, e.g. ultra-pure semiconducting materials.
13. Subject to the need for gaining sufficient influence, technology will represent a better investment than project management.
14. By ensuring that we retain a role in the core programme or a closely related area.
15. Yes, if we ensure that UK is involved in system level activities and we negotiate hard on the basis of a significant (GNP % minimum) participation in ESA's programme.
16. By having intimate knowledge of the user-oriented system interfaces and by carrying our share of the overall risk to buy indepedence.
17. Yes, if we establish a long-term strategy, act quickly to secure the opportunity without necessarily answering all the questions in detail and are prepared to devote some short-term national funding to catching up with our partners before and during Phase B.
18. Only if we can reverse the trend of history. Survival is probably the common motivation to ensure that a strong early commitment is made to the US.
19. I believe so, despite the current posture. Europe should not shrink from establishing its clear objectives for meaningful participation in the core programme and then negotiating an equitable relationship based on shared risk.
20. The UK must be careful to preserve its options to enable it to respond to the results of detailed study and to changes in the political or economic dimension.

PLATFORMS, MODULES & THE SPACE STATION

By Dr. Bob Parkinson*

The author adds further views on European participation in the US Space Station and considers what contribution British Aerospace may make.

Dr. R.C. Parkinson is currently Study Manager for Space Station studies at British Aerospace.

Introduction

The problem with giving *Spaceflight* readers an insight into the state of play in the question of European participation in the US Space Station programme is that the situation is changing so rapidly. It now looks probable that Europe will opt for a substantial participation in the Space Station programme. A figure of about $2000 million is being proposed, with fairly positive reactions from the ESA member states. Add to this a proposed participation of $1000 million from Japan and a similar, perhaps smaller, amount from Canada as support for the $8000 million US 'core' programme, then it seems probable that the 'US' tag to the Space Station programme may be misleading. Over a third of the total programme could be from non-US sources.

This money is not yet in place. Even the German government, which is proposed to take 50% of the European programme, has not formally agreed to spend such money, and in the first instance what will be committed is funding for the Phase B programme - approximately 80 million ESA Accounting Units. (An "Accounting Unit" is worth a little less than $1 or about 57 pence). Phase B is a two year design study exercise leading to the full development process afterwards (Phase C/D). European commitment to the Phase B programme has to be in place at the opening of 1985.

To prepare for UK participation in the European programme, a 'National Symposium on British Interests in International Space Station Proposals' was held on 4 October 1984, at the request of the Minister of State for Industry and Information Technology, Mr. Geoffrey Pattie. Attendance included senior members of the science research community, the Aerospace Industry and other interested parties. The BIS was represented by the President and Secretary, as well as other members (including the author) in their various official capacities. The concensus from this meeting was that if the UK is to remain active in Space it must pariticipate in the Space Station programme, and that participation should be substantial - 15% is the number most often bandied around. This number surfaced in the early summer and caused a little consternation in some European circles who had got used to the UK being 4% of similar programme (which puts it on a level with Spain). This level of space spending would represent an increase in UK budgets, but there are strong arguments that this is long overdue. German, French and Italian Space budgets have all been increasing at between 10 and 20% per annum (in real terms) for the past three of four years.

European Participation

On the basis that Europe is to invest strongly in the Space Station, what is it to do? Studies to answer this question have been underway for the past two years. The most publicised is the German/Italian Columbus proposal, which was carried out on German and Italian national funding and details of which have only just been made available to the rest of the world. Less well publicised was the ESA-funded 'Space Station Systems Study' (shortened to S-4 by its participants). S-4 involved 11 different companies from eight different countries, and looked at hardware participation in parallel with a 'European Unification Aspects' study (EUA for short) looking for potential users. British Aerospace was part of both studies.

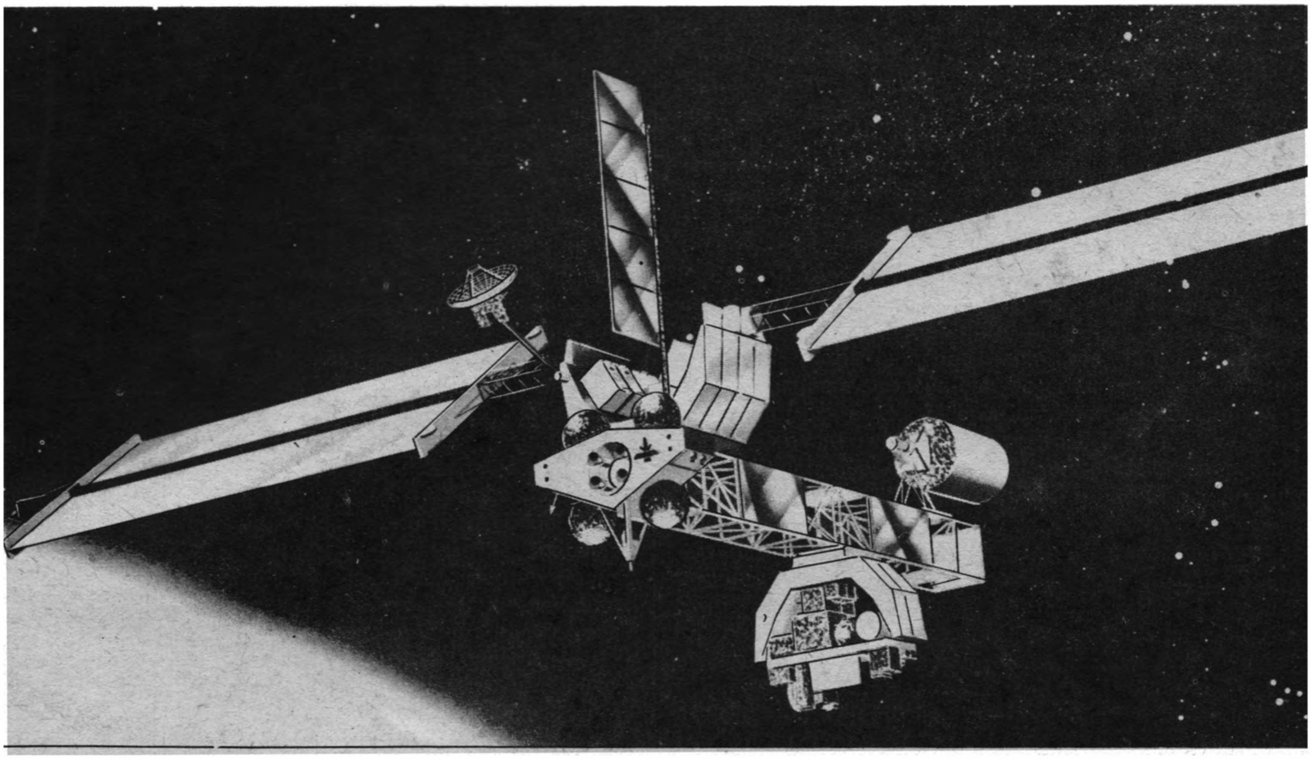
Both Columbus and S-4 came to similar conclusions as to the nature of European involvement. At the topmost level, it is generally agreed that Europe should produce a 'mannable' Experiment Module which can plug into the main Manned Space Station for its services, and an unmanned free-flying Space Platform which can carry payloads away from the immediate vicinity of the Space Station, but which would rely on the same manned infrastructure for servicing and payload exchange. If necessary these two units could, in the early 21st century, form the basis of an independent European Space Station. In addition, in an extended programme, Europe might choose to build a robot servicing and supply vehicle and a data relay satellite.

It may seem strange to include an unmanned, independent Space Platform as a contribution to the Space Station programme. The station itself is the permanently inhabited structure, although the NASA Request for Proposals issued in September 1984 also requests studies of the use of automation to the extent that even this 'core' Station might not need to be permanently manned in the early stages. The Space Station Programme also includes the requirement for a 'co-orbiting' Platform periodically returning to the Manned Station, a polar orbiting Platform, a reusable, cryogenic Orbital Transfer Vehicle for lofting payloads to geosynchronous orbit, and an Orbit Change Vehicle capable of placing and recovering satellites in lower Earth orbits. Not all of these will be paid for out of the initial $8000 million. The Orbit Change Vehicle is being funded earlier that the main Station - but all form part of the Space Station Infrastructure.

British Aerospace consider the Space Platform to be an important element in European participation. Europe will not only have to build components of the Space Station, it will have to support it in operation. It will also have to buy facilities aboard that part of the Space Station it does not build. It is therefore highly desirable that whatever Europe builds, it attracts not only European users but US users also. Then US usage of European elements can be traded *quid pro quo* with European usage of US facilities. A plug-in Experiment Module supports only European users. The correct Space Platform, particularly one in polar orbit, would attract users from all sources.

British Aerospace are arguing that the UK should take a lead in the Space Platform part of the European participa-

* The situation described in this article is as existed in mid-October 1984.



A British Aerospace concept for a Space Platform.

tion programme. Since the Platform accounts for only about a quarter of the total budget, the UK contribution would account for rather more than half of this element. Further, it can be argued that the Platform supports UK interests in space rather better than other elements.

Part of our studies have involved looking at the sources of user funding. Most of the attention given to the use of Space Station facilities has focussed on microgravity processing - manufacturing semiconductor crystals or exotic pharmaceutical products under zero gravity. There is reason to expect microgravity processing to assume a growing importance as we enter the Space Station era, but even with optimistic projections into the 1990's microgravity budgets are likely to remain well below European spending on Space Astronomy and Earth Observation. Earth Observation (resources, meteorology) are not 'commercial' users in the sense that private companies invest in, but they are important public sector services. Because of this there is an immediate demand for a polar orbiting Platform (perhaps even more than one), and derivative 'co-orbiting' Platforms can follow.

The Space Platform being proposed by British Aerospace is a modular, highly adaptable structure. At its heart is a Resource Module which provides the power supply to payloads, an active cooling loop, data collection and communications services as well as overall Platform control. Each of these services is boxed in detachable 'Orbital Replacement Units' (ORUs) which can be replaced on-orbit by astronauts or a robot servicing vehicle at periodic maintenance visits. The services provided by the Resource Module are transmitted to payloads *via* a Payload Beam, which carries berthing points at 6 m intervals at which power, cooling and data connections are available. Payload Carriers could look like Spacelab Pallets with a berthing interface added, carried up as standard units in the Space Shuttle and plugged into appropriate points on the Payload Beam. Alternatively, instruments like astronomical telescopes which have to be directed towards different parts of the sky would be mounted on an Instrument Pointing Module similar to that developed for Spacelab, which in turn would be mounted on the Payload Beam. The platform is completed by a Propulsion Module, capable of boosting the Platform from Space Station/Space Shuttle atltitude to its operating altitude (about 800 km), and later returning to the lower altitude for servicing. By making this a separate Module it can be simply replaced, rather than demanding on-orbit refuelling.

In its initial configuration, the British Aerospace Space Platform is designed to deliver a total of 12 kW payload power to five berthing points, and to cope with the collection of up to 272 Mbps of data from a multiplicity of experiments for relay through a data relay satellite like TDRSS. The Platform would be delivered complete into orbit, including the first Pallet load of payloads, in a single Shuttle launch and assembled *in situ.* Not only is the Space Platform the world's first permanent satellite in the sense that every part can be replaced on-orbit, it is also likely to be the first (excluding the Space Station itself) to be assembled on-station. Rather than developing complex mechanisms for the deployment of antennae, radiators, solar arrays etc., it actually appears cheaper and more effective to deploy astronauts for a six hour EVA to carry out these activities.

Since it represents a permanent facility in orbit, it is cheaper to fly payloads on a Platform than as independent satellites. Not only does the service 'bus' of the satellite not have to be launched each time, but the cost of providing these services can be amortised over a larger number of users. Our calculations indicate that the Platform represents a saving of up to 50% on 'launch and facility' costs over conventional multi-mission spacecraft. To achieve these savings, a Platform has to acquire just two new payloads a year.

Whether or not the British Aerospace Platform is adopted as part of the European participation in the Space Station programme will be decided soon. The grounds will be political and economic, not technical. It would be a big boost to UK Space interests to have a British flag flying on such a major element of the programme in the 1990's, and a good deal of effort is currently underway to ensure that it is so.

US MANNED SPACE STATION: GENERAL IMPLICATIONS

by Peter G. Whicher

A further paper presented at the Dept. of Trade and Industry on 4 October 1984 discussed the philosophy behind a manned Space Station. The author is Deputy Director (E) of the Royal Aircraft Establishment in Farnborough.

Introduction

In space, flights of fancy have often preceded the technology and finance required to support real space projects, with the result that almost every new advance has attracted its full share of scepticism. Space history has shown, however, that money, time, research and good engineering can overcome the most formidable problems. The technical and scientific achievements of the Apollo programme pioneered the active role of man in space exploration and there is no reason to doubt that the manned Space Station proposals are entirely achievable, given adequate resources and commitment.

In spite of advances in automation and robotics, experience in the sea and air environments has shown that human qualities remain valuable for rôles in which initiative, adaptability, perception and originality are important. There is no reason to believe that space will be different and the remarkable achievements of astronauts bear witness to their unique rôle.

The Case for Men in Space

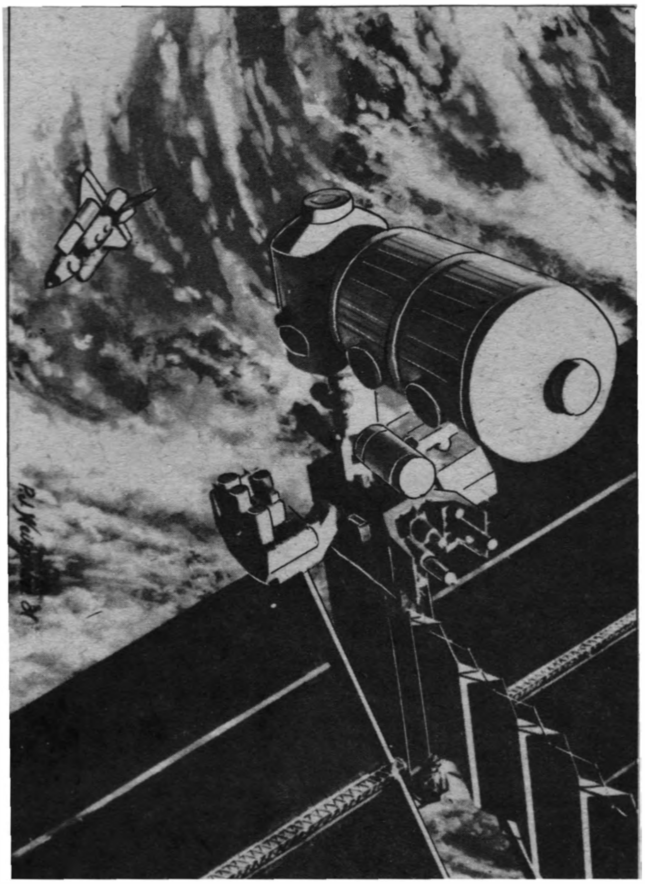
We should not too hastily discount the value of man in space in spite of advances in remote control and robotics. At sea and in the air, both more established environments, both civil and military operations see a continuing role for man. The reason usually given is that it will be a long time before automata can mimic human enterprise, flexibility, inspiration and commonsense. It is difficult to see why space should be different. As in the other environments there are places for unmanned vehicles and robotics, and opportunities for man.

A constructive use of man in space is to assist in system development and optimisation. For example, in remote sensing the perceptive powers of man, if available in a 'man-tended' spacecraft, could be used to help optimise the selection and use of on-board sensors and signal processing, using equipment which may be too complex or vulnerable for totally unattended use.

Industrial and chemical processing, space science and the biological disciplines can all demonstrate new opportunities within the space environment, although the economic returns cannot yet be gauged. The US manned Space Station will, however, probably be the largest and heaviest structure assembled in space and UK participation should, above all, gain us experience in this vital area of development.

Even the largest current spacecraft are limited in capability by launch constraints. Key parameters such as electrical power, antenna gain and directivity, sensor size, signal processing capability, particle shielding, manoeuvring and redeployment capabilities have all been limited. Spacecraft lifetime has also been shortened by lack of maintenance, repair and refuelling facilities.

Communications satellites, for example, require larger



A 1982 TRW Space Station concept.

and more complicated antenna farms to accommodate intersatellite links; large antennae for ground links so as to reduce spillover pollution allow better use of the limited frequency spectrum, and bring ground station tests and antenna sizes down to compete with those of normal terrestrial systems. Only then can one of the main benefits of satellite systems - i.e. delivery of the speech, data or images *direct to the end user,* be fully and economically realised.

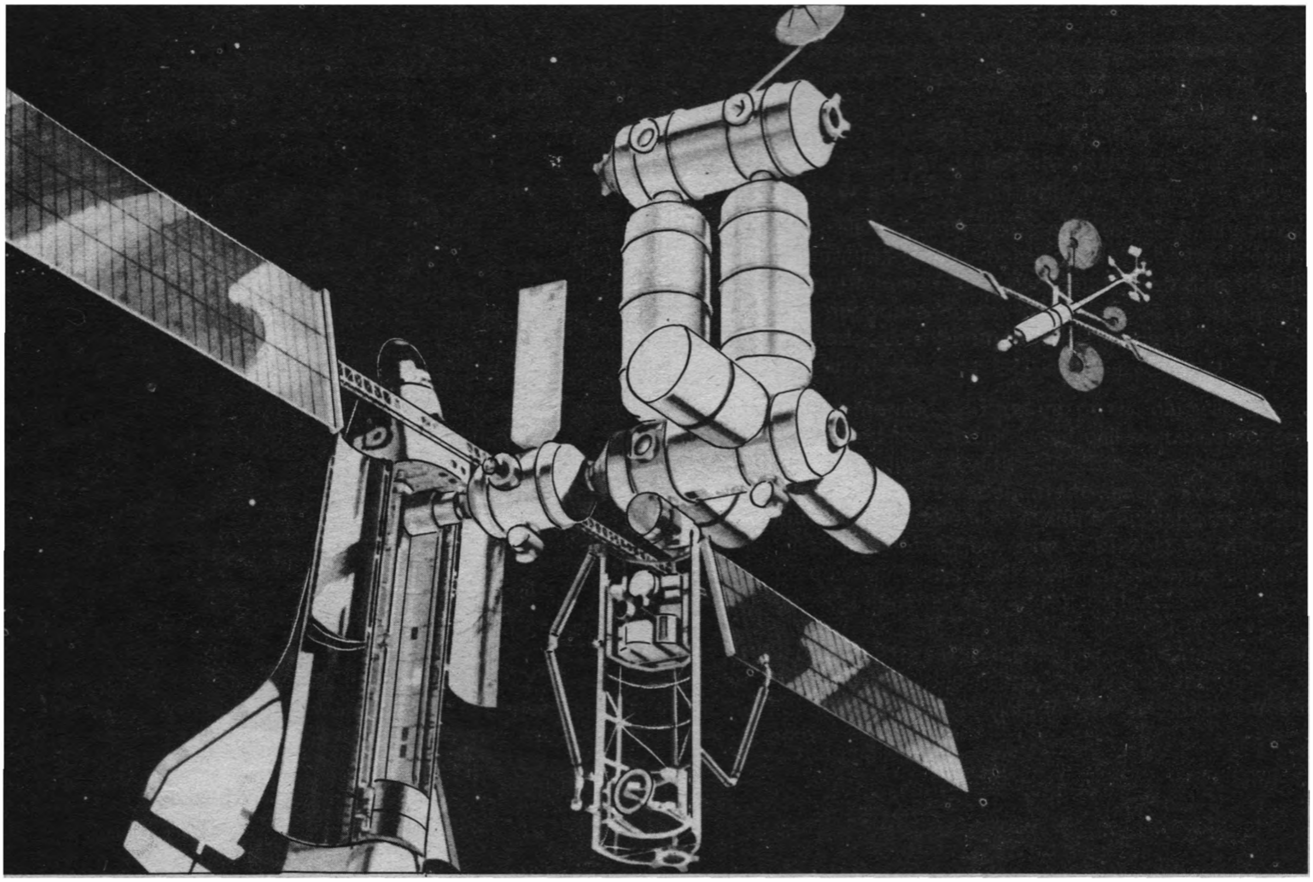
The ever larger and complex satellites that will be needed in the future for this sort of task will, in many cases, have to be assembled and later tended in space. The unmanned Space Station is a significant step in the chain of events which will lead to this capability and in which UK now has a chance to participate.

It is interesting to note the analogy between the development of ships and spacecraft. Each originated with small craft of limited capabilities, severely constrained by the limitations of early technology. In both cases, however, the requirements have constantly multiplied, leading to the development of a wide variety of ever larger craft as techniques have advanced.

Thus, in space, one can foresee ferries, equipment carriers, fuel tankers and specialised research and military vehicles. But the marine development of greatest potential to emulate is the container ship - substantial in size and designed to carry its payload in a large number of standard modules - the ship itself providing a robust propulsion, stabilisation, power generation, navigation and communication infrastructure, and possibly accommodation for regular or occasional operating and maintenance crews. The space station concept is about halfway along the current evolutionary scale for maritime craft.

The Way Ahead

To return, however, to the immediate problem of the


An early 1984 station concept.

space station, three fairly firm assumptions can be made:

1. The US Space Station is likely to go ahead.
2. Germany and Italy will proceed with some form of Space Station probably through ESA.
3. France will wish to advance Ariane and Hermes proposals.

Against this background, UK policy should also take into account that:

1. The demand for larger spacecraft will increase and will need to be matched by increases in UK investment and constructional capabilities in order to retain our competitiveness.
2. The total scope for man in space is still arguable but at least three tasks are becoming accepted:

   a. Assembly and test of large spacecraft and structures which are too big or too complex to trust to a single unmanned launch.

   b. Repairs in space. These will become increasingly cost-effective as spacecraft become more modular and/or as the items to repair become larger and more expensive.

   c. Technological innovation. Ideas stem from necessity, challenging situations, new environments and mental inspiration. The manned space environment offers all these stimuli to participating engineers and scientists.
3. Success in space carries an element of prestige.

Conclusions

Returning to the opening question of the general implications for the UK of the Space Station and associated developments, a few simple conclusions are possible.

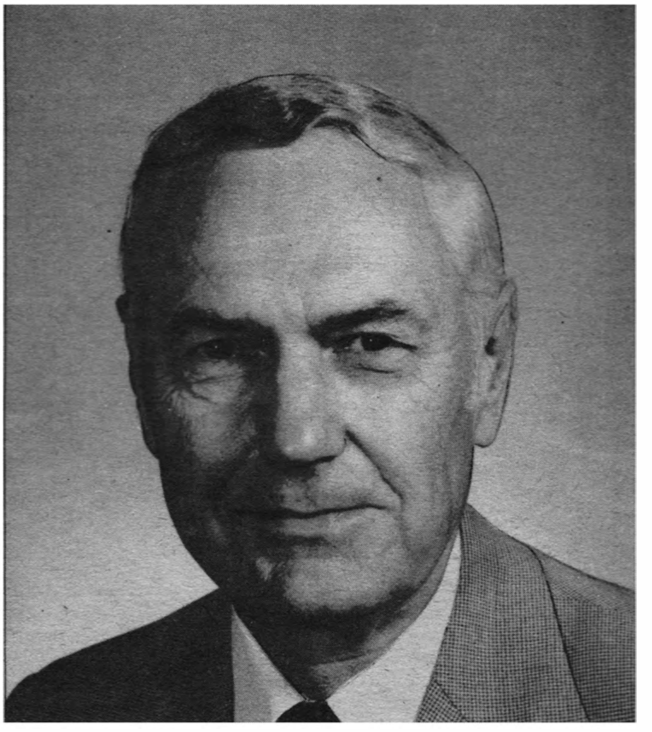
1. Shuttle, Ariane and possibly Hermes offer a useful spread of launch capabilities. It is probably too late economically for the UK to go back into building conventional launchers. Trans-atmospheric vehicles and ion engine propulsion are, however, fields worth further examination.
2. Of Columbus and the Space Station, the latter is probably half a generation ahead in concept and substance, It is based upon standard modules and the concept is expandable and adaptable. (It may be possible for the Space Station Programme to absorb Columbus, but hardly the converse). Thus, if UK wishes to participate in the most advanced space programme, the SSP has a decisive edge.
3. If the UK is to participate in the SSP, the most favourable course would appear to be by a robust contribution to ESA's participation so that the UK may negotiate some 'noble' work on both the manned and unmanned elements of the programme.

The precise method and extent of UK participation in the platforms and the Station itself will require extensive discussion nationally and with ESA. The UK technological base, however, should be adequate to secure a worthwhile role in both the technological and human aspects of this very far-reaching enterprise, which is likely to influence civil space developments until well into the next century. It is an opportunity that should not be lost.

Note: The views expressed in this paper are those of the author, and do not necessarily represent the opinions of the Royal Aircraft Establishment or any Government Department.

TO THE MOON?

Now that the Space Station is underway, many feel that a return to the Moon should be the next step. NASA is already making initial studies for bases on the lunar surface and in October 1984 NASA Administrator James Beggs made a significant speech in Washington DC to a symposium on future space activities. An adapted version of his presentation is given below.



NASA Administrator James Beggs. *NASA*

NASA's lunar base working group met last April at Los Alamos to debate the pros and cons of establishing a permanently manned base on the Moon's surface. The working group concluded that such a base should be adopted by NASA as a long-term goal for the 21st century.

Even before Apollo, our studies concluded that such a base could serve as a facility for scientific research, economic exploitation of the Moon's resources and colonisation of the Moon.

Today, more than 15 years after we first set our footprints on the Moon, we have learned much about it. Twelve Apollo astronauts walked on the lunar surface; they returned more than 2,000 samples of lunar rocks plus cores of soil from six locations. Soviet unmanned spacecraft have provided samples from three other sites. Spacecraft have photographed the entire Moon from orbit and performed chemical analysis of more than a quarter of its surface.

Our lunar exploration revealed no water, no organic matter and no living organisms. But the Moon rocks contain the secrets of more than 4,500 million years of lunar history. We know now that the Moon not only has plentiful oxygen in its rocks, but also silicon and possibly valuable metals such as iron and titanium.

I believe it highly likely that before the first decade of the next century is out, we will, indeed, return to the Moon. We will do so not only to mine its oxygen-rich rocks and other resources but to establish an outpost for further exploration and expansion of human activities in the Solar System, in particular, on Mars and the near-Earth asteroids.

Now that the Shuttle is proving to be the reliable and versatile machine its designers intended, we will use it to help meet our next major challenge. This will be to develop a permanently manned Space Station in low Earth orbit within a decade, as the President directed us to do.

We expect that, by the year 2000, the Space Station will be equipped with a supporting infrastructure that will enable us to operate routinely at both low Earth and geostationary orbits and between them; and, eventually, at distances as far as the Moon and the inner planets. Two key elements of this infrastructure will be reusable and might be compared to a local taxi and an intercontinental airline.

The former is called the Orbital Manoeuvring Vehicle. It will be used to service satellites close to the Space Station and for other tasks. The latter, known as the Orbital Transfer Vehicle, will ferry payloads to and from geosynchronous orbit or launch spacecraft to the Moon and other points in the Solar System.

This enabling technology will permit us to engage in a variety of manned and unmanned activities in space. It will spur exploration and the commercial use of space. It will invigorate Earth applications and stimulate sustained research and development on innovative systems and techniques. It could also trigger extensive initiatives to benefit life on Earth, such as satellite power systems and nuclear waste disposal systems in space. It will be the key to future more ambitious missions, such as a manned mission to Mars, the capture of an asteroid, or large automated deep space and planetary probes.

One of those missions could very well be the establishment of a permanently manned lunar base. Many crucial considerations - technical, scientific, political, economic and social - will guide future public policy decisions on a permanently manned lunar base. I'd like to single out just three. First, what should we be doing, if we establish permanent roots there, to make our presence most productive and beneficial for mankind?

Next, we know that any enterprise of the magnitude and scope of a permanently manned lunar base would be an enormous challenge. This implies even greater international cooperation and international sharing of risks and benefits in the future.

In this connection, we expect our friends and allies to accept President Reagan's invitation to join with us in developing the Space Station. Such cooperation could lay the groundwork for even greater international collaboration in space for the future.

A third consideration is technological. If we were to mine the Moon, how would we go about it? Many methods have been proposed but none have been proved.

At present, we know how to extract valuable materials from ore deposits on Earth, but Earth's ore deposits are unusual in that their valuable elements are highly concentrated and relatively easy to extract. Moon rocks and meteorites are different. Their key elements are not concentrated and are hard to extract and we have no Earth-based technology at present that could do the job.

Clearly, such a technology will have to be developed if we are ever to mine the Moon. That's why we should begin soon, on a small scale and in a preliminary way, to study how to extract useful minerals from lunar rock and soil.

In space, as on Earth, there are rich dividends and enormous benefits for those who are able to muster the resources, know-how and vision to follow their dreams.

CORRESPONDENCE

Space - A New Beginning

Sir, Engineering has always been a significant factor in the crossing of frontiers, the meeting of different peoples and the increase in understanding between nations. This is nowhere more evident than in space engineering.

In the space business the need for a highly professional approach is clear. It is a paramount ingredient for success, to which one has to add enthusiasm, motivation, vision and some boldness in the commercial area. Brunel would surely have been in the front ranks had he lived in the Space Age.

All these factors contribute to making space activity a significant positive contribution to understanding between nations.

The tentacles of the space business spread across a vast number of disciplines and countries. In so doing they bring together diverse interests and nationalities and stimulate the young. This is, I suggest, a significant and healthy factor for the future which those who have been amongst the first in this area of human endeavour have always hoped would happen.

In the course of 20 years in the business, I have met people in many diverse fields, ranging from university scientific communities to the large list of establishments and their various committees. The great space enterprise embraces a wide range of different groups drawn into this exciting business. Besides hardware manufacturers, communications satellites bring in other disciplines, while the entertainment industry adds yet more, to which should be added national and international organisations as well as those in the fields of legal expertise, insurance, banking and entrepreneurs of all sorts.

In due course, social activities tend to follow. One such example, starting from relatively humble beginnings, is the annual 'Ariane Cross.' It consists of several medium distance races for juniors, seniors and veterans of both sexes and is held at the various Ariane project contractors.

It is now a professional affair with well organised races and trophies awarded for each event and with a main prize for the winning team. The UK team have participated for the last five years or so with considerable success, having won the team event on occasion and usually managing to win one or more of the individual events. There is tremendous competition among participants. Last year, for example, there were over 500 runners and about 600 people attending.

The most sceptical reader should agree that an old dream is, indeed, coming true. Nowhere is this more apparent than the latest example in the initiative of President Reagan with the US Manned Space Station. This could develop into a powerful political initiative for a joint endeavour in space and almost certainly lead to the provision of various parts of the Space Station by Europe, Japan and Canada, with contributions to a joint programme and an operational structure involving European, Japanese and Canadian personnel.

PETER CONCHIE
Director, Business Development
British Aerospace Dynamics Group
Space & Communications Division

The Editor is always interested in receiving items of correspondence, notes, comments, or reviews for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine. The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.

Soviet Launch Vehicles

Sir, I read with astonishment (*Spaceflight*, November 1984) about the Soviet so-called Heavy Lift Shuttle. Simple computations show that the payload (if launch mass/thrust are correct) to 180 km orbit will be 30 ± 10 tonne with the lower regime more likely. Possibly the 96+ tonnes quoted refers to the total mass orbited.

The other two new launch vehicles are, at least, consistent, but I wonder if the Medium Vehicle makes sense. It is very similar in performance to the Proton launcher.

Direct discussion with Soviet engineers produced the following information:

1. The Cosmos test model is purely for research/technology and is not connected with a specific follow-on project.
2. The Heavy Lift Shuttle does not exist (other than in several conceptional plans) of which the design shown is jut one of the configurations studied.
3. No decision has been made to use H_2/O_2 propellants.
4. The Heavy Lift Launch Vehicle is real.

This information, to me, has the ring of truth, but we shall see.

PROF. HARRY RUPPE
Technical University, Munich
W. Germany.

Lunar Rover

Sir, I came across a mention recently to plans to convert the American Surveyor lunar soft-lander into a rover to move around the Moon under control from Earth. Can you shed any further light on this?

RAY SWEETMAN
London

Reply:

There was a firm intention to produce a Surveyor-type lander with wheels several years before the Soviets used their Lunokhod vehicle on the Luna 17 and 21 missions. The photograph shows a full-scale working model. Delays in the Surveyor/Centaur programme (the final landing was made by Surveyor 7 in 1968) pushed the rover so far back that the imminent Apollo landings made it unnecessary. The Surveyor rover is described in the paper 'The Making of a Moon Rover' by Dr. M. Bekker in the next 'Astronautics History' issue of *JBIS*.

US Navy Satellite

Sir, Regarding the letter (*Spaceflight*, 1984, p.392) on the US Navy satellite, I feel that the identification of 83-08B might be in error.

When the USAF announced that an Atlas had been launched on 9 February 1983 from Vandenberg, myself and G.E. Taylor undertook a programme of optical observation of the two objects being tracked (83-08A and B) in order to determine whether or not this was a follow-on Noss after a three year gap, or a completely new version. On 16 February, after earlier nights of unsuccessful sightings, the A and B pieces were seen at magnitude +7 steady, at a range of 1200 km, 60 degrees

in the East. No other pieces were seen while the payload and rocket (Burner derived?) were in view. In comparison with earlier Noss observations, the magnitudes tied in well with previous launches.

If LIPS had been deployed from 83-08A, then surely it would have been tracked almost immediately after launch, instead of on or before February 20th, when the C piece appeared. My own thoughts are that, although the Navy object may have gone up on this launch and be hidden among the debris, a far more likely candidate is 84-12, where NORAD have catalogued up to the L piece at present, slightly more than usual for a recent Noss cluster.

MAX WHITE
Satellite Camera Team,
Royal Greenwich Observatory

Mercury and Gemini Pictures

Sir, During the last Mercury mission (May 1963), a TV camera was used for the first time on an American manned space flight. The pictures of Gordon Cooper were said to be hazy and possibly, because of this, they have never been used in books. Or have they?

During the Gemini 10 mission, Michael Collins did a space walk to the Gemini 8 Agena docking target but the films were of poor quality and they were not widely seen. It would be interesting to see stills from this film.

JOHN COLLIER
California, USA

Reply:

Michael Collins, in his autobiography, points out that he took some very spectacular pictures during his EVA. The only problem was that he then lost the Hasselblad camera, which thus became the first Swedish satellite in orbit!

On Gordon Cooper's flight in 1963 the 5 kg TV camera was used to transmit picture s of the astronaut's head area for medical observers. It was used for less than a total of two hours since only three ground stations were equipped to receive the signals. Some pictures were used by the TV networks.

Get it Right!

Sir, I still occasionally hear space lecturers refer to 'Cape Kennedy!' The media often get this wrong but we can hardly complain when those who should know do so too. The name of Cape Canaveral, which was changed to Cape Kennedy after the assassination of President Kennedy in 1963, was reinstated in 1973.

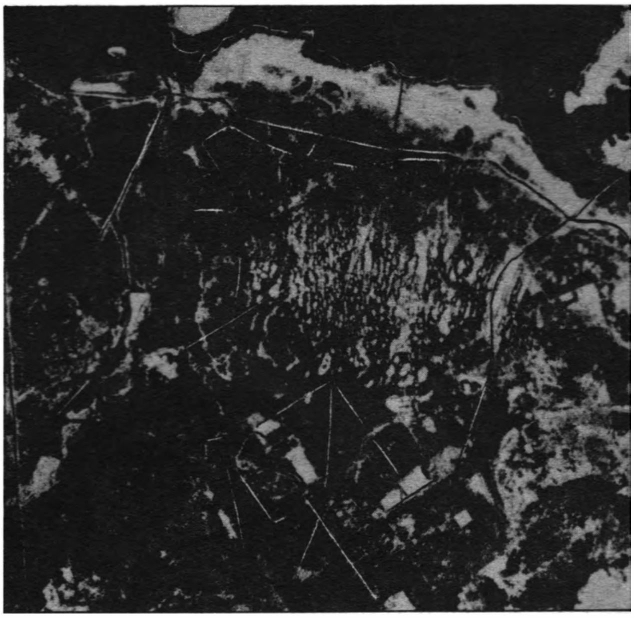
I wish the media would also note that Kourou is in French *Guiana*, not French *Guyana.* No doubt this confusion arose because when the neighbouring colony of British Guiana became independent it took the name of Guyana.

RAY WARD
Sheffield

Confusion sometimes arises because the name 'Kennedy Space Center' is, of course, in use. We have heard people within NASA itself refer to Cape Kennedy! -Ed.

Archaeology from Orbit?

Sir, I am a keen observer of both the archaeological and space scenes and am wondering if archaeologists have used images taken from orbit for their work. I know that the radar carried on one of the early Shuttle missions discovered ancient riverbeds under the sands of the Sahara but have satellite images yet been used in the same way as aerial photographs?



The Shuttle Imaging Radar carried on mission STS-2 in November 1981 probed below the sands of the Sahara to reveal ancient river beds. This is an area in central Florida. Mission 41G in October 1984 carried a more advanced version of the radar capable of resolving finer detail. *NASA*

MAX WHOLEY
Midhurst, Sussex

Reply:

We know of no specific cases where satellite images have been used for small-scale studies, e.g. tracing the outlines of old buildings, as have aerial pictures. The normal resolution of Earth resources satellites is probably too poor for this type of activity - the military level of capability would be necessary. We would be interested to know if readers have any additional information.

SNIPPETS

It's the Best!

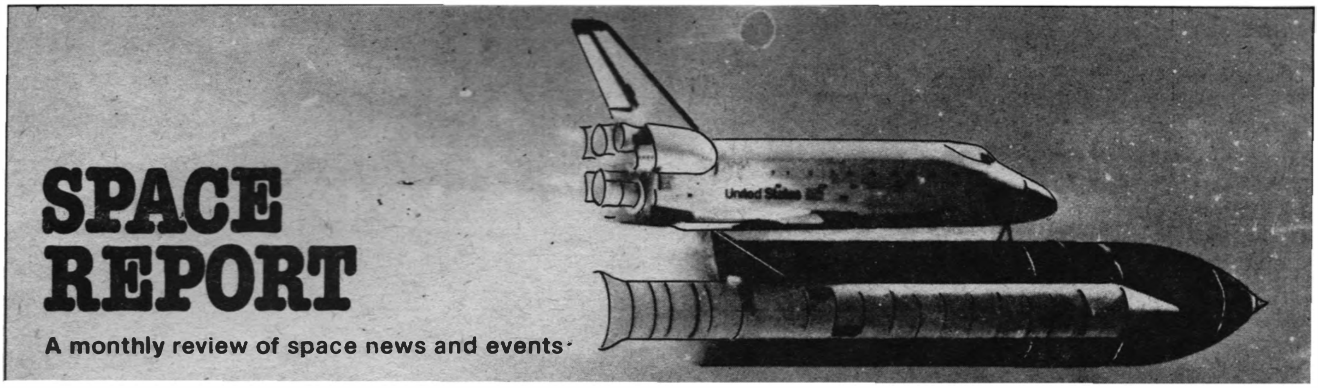
Sir, In my three years as a Society member this is the first time I have written to you. On receiving my renewal form recently, I realised what a bargain it is to be a member - £21 a year for the superb *Spaceflight* magazine, and the opportunity to attend Society meetings.

MICHAEL PHILLIPS
Gillingham

Coincidence?

Sir, When the 51C Shuttle mission was postponed until early 1985 that made a total of five Shuttle missions in 1984 - four less than planned. A pattern of one extra flight each successive calendar year seems to be emerging. Two for 1981, three for 1982, four for 1983 and five for 1984. I wonder if the pattern will be continued in 1985, with six flights regardless of the 13 or so planned. If so, at this rate NASA's goal of 24 missions per year will not be realized until AD 2003!

IAN KNOWLES
Leeds



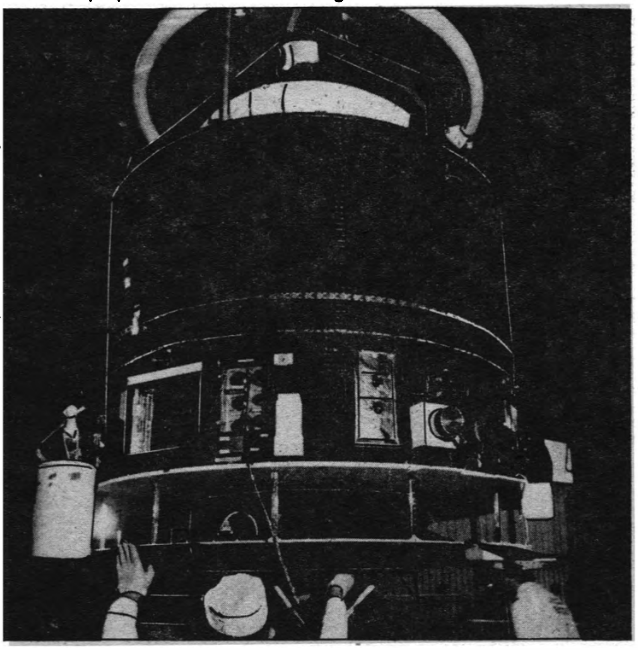
SPACE PROBES

GIOTTO UNDER TEST

The Giotto Halley's comet probe completed its thermal tests at the Centre Spatiale de Toulouse last November in preparation for launch in July. The environmental test programme, consisting of solar simulation, thermal vacuum, acoustic and vibration tests, began last August. Following completion of the thermal work, Giotto entered the final phase with spin balance and demagnetisation tests. Delivery to the European Space Agency's Technology Centre at Noordwijk, is scheduled for early spring and shipment to Kourou in French Guiana will be made during the second half of April.

All of the environmental tests were conducted on the completed flight spacecraft. During solar simulation tests, which lasted for 15 days, the spacecraft was spun at a rate of 10 rpm in a vacuum chamber and positioned at different angles to simulate the thermal rigours of launch, cruise and encounter with the comet. The behaviour of the thermal design was monitored throughout by 300 thermocouples. To prove the mechanical design, the acoustic and vibration tests simulated the conditions of the Ariane launch vehicle. The acoustic work was conducted in a special chamber at noise levels greater than those the human body can tolerate to represent the roar of Ariane's engines.

Giotto is prepared for thermal testing. *BAe*



SPACE SHUTTLE

DELAY OF 51C

Shuttle mission 51C, carrying a classified US Dept. of Defense payload, was delayed from the original 8 December launch target because of problems with the thermal tiles. The decision was made on 5 November to replace up to 2,800 thermal protection tiles on the underside of *Challenger* because of the degradation of the bonding material.

When *Challenger* returned from space on its last mission in October 1984, a black tile from the left wing chine area, just behind and below the crew door area, was missing. About 100 tiles were removed and it was found that the adhesive substance known as 'screed,' used to smooth irregularities in the surface of the Orbiter, had softened. This white, Room Temperature Vulcanizing (RTV) material is used in much the same way that body putty is used on a car. It hardens and can be sanded smooth after it dries.

The screed is used on areas of the body of the Orbiter, such as the underside of the fuselage, body flap, elevons and the sides. It is applied directly over the aluminium skin. All other areas are covered with a primer called red RTV-560 which is used as an adhesive for bonding the strain isolation pads (SIP) to the body and the tile to the SIP.

The NASA crew of Tom Mattingly (commander); Loren Shriver (pilot), Ellison Onizuka and James Buchli (mission specialists) will be joined by USAF specialist Gary Payton as the first of a group of non-NASA astronauts dedicated to Dept. of Defense missions. This will be the first Shuttle mission to use the Inertial Upper Stage since the failure during STS-6 in April 1983. Its payload remains classified.

51C: the Dept. of Defense classified mission originally scheduled for 8 Dec. 1984 was slipped to 22 Jan. *Discovery's* crew is Mattingly, Shriver, Buchli, Onizuka and Payton.

51B: *Discovery* should have flown in January with Spacelab 3 but now moved to April with its crew of seven.

51E: the launch of the second TDRS communications satellite will still go ahead for 18 February, with astronauts Bobko, Williams, Seddon, Hoffman, Griggs and Frenchman Patrick Baudry.

51D: the release of a Leasat communications satellite and the retrieval of the LDEF left in orbit by 41C last April is still scheduled for 18 March with astronauts Brandenstein, Creighton, Lucid, Fabian, Nagel and Jarvis.

Later flights will also be affected; information will be published in *Spaceflight* as it comes to hand. The dates given above were current at the end of November 1984.

SHUTTLE ASSIGNMENTS

NASA has named five astronauts for Shuttle mission 51I, scheduled for August, and changed one previously announced assignment on another flight.

Mission 51I will be commanded by Robert Gibson, who served as pilot on 41B. Charles Bolden will be his pilot. Mission specialists are Drs. Franklin Chang-Diaz, Steven Hawley and George Nelson. 51I will be Chang-Diaz's first trip into space; Hawley was a mission specialist on 41D and Nelson flew on flight 41C to rescue the Solar Max satellite.

The seven-day mission, using Orbiter *Columbia,* will carry two communications satellites, Syncom IV-4 and the American Satellite Company's ASC-1, and a materials processing experiment designated MSL-2.

in a crew change, Roy Bridges has replaced David Griggs as pilot on flight 51F (Spacelab 2) in July 1985. Griggs has also been assigned as a mission specialist on flight 51E in February. The change was made because the proximity of those two flights allowed insufficient time for training.

Flight 51E will carry the second Tracking and Data Relay Satellite (TDRS) and another communications satellite, Telesat I. Flight 51F is the Spacelab 2 mission.

CRIPPEN APPOINTMENT

Astronaut Robert Crippen, who completed four Shuttle missions with 41C last April, has been named as the deputy director of flight crew operations at Johnson Space Center. George Abbey continues as director. Crippen will remain on active flight duty. A US Navy Captain, he was pilot of STS-1 and commanded STS-7, 41C and 41G. He joined NASA in September 1969 after three years of duty with the US Air Force's Manned Orbiting Laboratory programme.

TEACHER IN SPACE

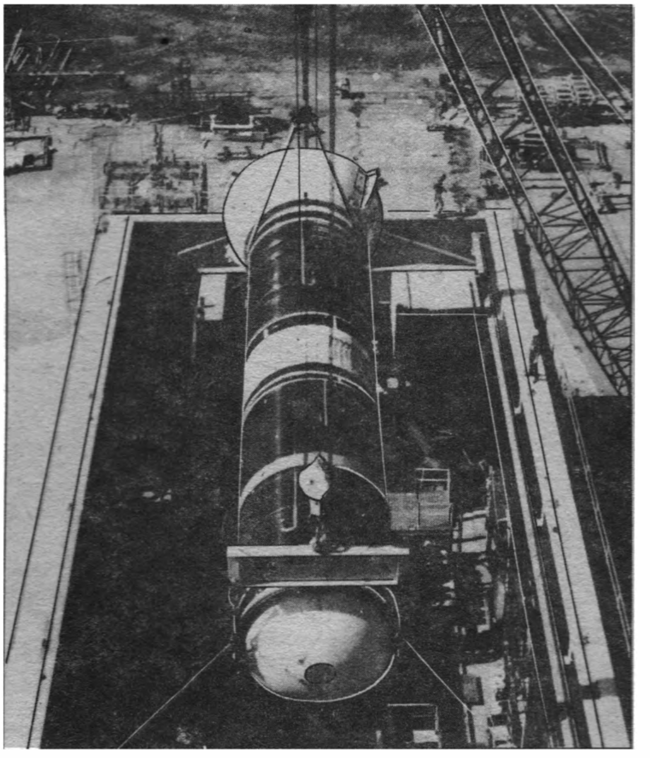
President Reagan's proposal to carry a schoolteacher in an early 1986 Shuttle flight had produced 6,000 enquiries by the end of last October, according to Alan Ludwig who is in charge of the project for NASA. The agency expected to make a formal announcement in November. Applications will be received until 1 February. To be eligible, a candidate must be a US citizen and a full time teacher at elementary or secondary level. He or she must be in 'reasonably good health and be able to walk on and off the Shuttle without help.' Blood pressure must be under 160, vision corrected to 20/40 in one eye and the person must be able to hear a whispered voice at a distance of 1 m. Applications will be screened by the Council of State School Officers Association, after which the chief educational officer of each stage will select nominees. They will attend a workshop, after which a national peer group will recommend 10 semi-finalists by July 1985. This group will undergo tests at Johnson Space Center and the field will be narrowed to five. NASA Administrator James Beggs will choose a primary and backup in September 1985 for eight weeks of training.

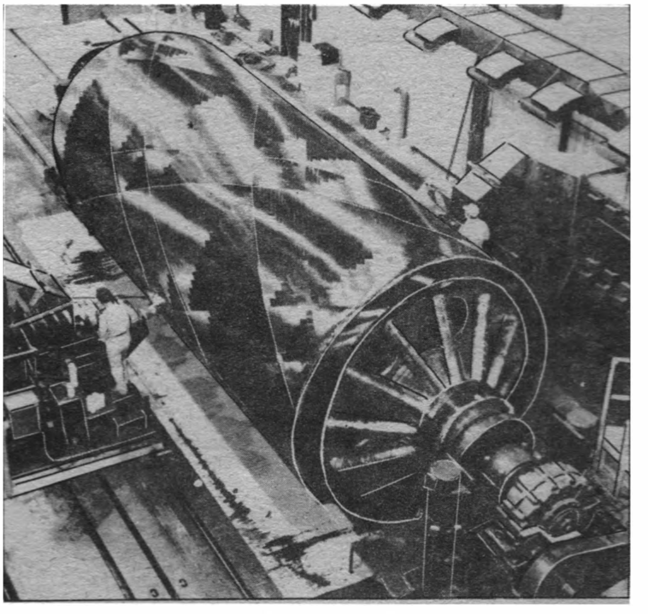
SHUTTLE PARACHUTES

Larger main parachutes were a part of the Shuttle solid rocket booster's deceleration system during mission 51A, launched on 8 November 1984. The main 'chutes are designed to slow the boosters down for a safe descent into the ocean.

The new parachutes are 41 m in diameter, compared to previously-used 35 m 'chutes. According to Keith Henson, booster recovery subsystem manager in the Shuttle Projects Office at NASA's Marshall Space Flight Center, the larger versions reduce the impact velocity from 97 km/hr to 82 km/hr in order to relieve the structural loads by about 25% thus reducing the damage.

Three main parachutes are used on each booster.





The first firing test of a new light-weight Shuttle booster was carried out on 25 October 1984. The casing is a composite material of plastic reinforced with graphite fibres wound into a cylinder. Each booster thus weighs about 13,600 kg less than the older steel versions, allowing the Shuttle to carry 2100 kg more payload. Two firing tests are planned for 1985 and the first flight is intended to be from Vandenberg Air Force Base in October. The steel versions will continue to be used in missions where weight is not critical. *NASA*

Following launch and separation from the Shuttle, the boosters are recovered from the ocean, refurbished and used on a later flight.

According to Henson, the larger 'chutes were tested during mission 41D in August 1984 on the right booster. Beginning with mission 51B, scheduled for early 1985, all future steel case boosters will have the larger 'chutes.

Smaller main 'chutes will continue to be used on some missions, including the 51C mission in January and on missions where lighter-weight filament wound booster motor segments are flown. First use of those segments is planned for October 1985.

SATELLITES

ARIANE 3 LAUNCH SUCCESSFUL

The second launch of the more powerful version of the European launcher, Ariane 3 was successfully completed on 10 November 1984 carrying two communications satellites, Spacenet 2 and Marecs B2. The Marecs satellites allow transmission of high quality voice and data services between ships at sea (about 3000 at present) and shore stations connected to the terrestrial telephone network. This also includes the relaying of ship to shore search and rescue messages. The first of the series was successfully launched by Ariane L04 on 19 December 1981 and has since been providing maritime communications services over the whole of the Atlantic Ocean region. Marecs 1 was lost because of the Ariane L5 launch failure; Marecs B2 is its replacement. Spacenet 2 is a commercial US satellite.

SUCCESSFUL NOAA LAUNCH

The NOAA 9 meteorological satellite was launched from Vandenberg Air Force Base in California on 1 December 1984 into an 870 km polar orbit. The NOAA satellites, apart from imaging weather systems, collect meteorological readings and transmit the information directly to users around the world for local weather analysis and forecasting. Information is used for hurricane tracking and warnings, agriculture, commercial fishing, forestry, maritime and other industries.

Special instrumentation was carried as part of an international, life-saving programme that makes use of satellites to rescue people from crashed aircraft and ships in distress. The project, with primary participation from Canada, France, the Soviet Union and the US started in September 1982 and has saved about 300 lives.

NOAA 9 is the latest in a series of RCA-built Tiros weather satellites dating back almost 25 years to Tiros 1, launched on 1 April 1960. It is the sixth in the current series of 11 satellites developed to give scientists comprehensive meteorological and environmental information. It was built at a cost of $43.5 million, with an additional launch vehicle cost of $11.4 million.

Tiros N (Television and Infrared Observation Satellite) was the first in a series of third generation operational environmental satellites. It was launched on 13 October 1978 and was a research and development prototype for the operational follow-on series, NOAA A to G. Advanced instruments measure parameters of the Earth's atmosphere, its surface and cloud cover, solar protons, alpha particles, the electron flux density, the energy spectrum and the total particular energy disposition at the satellite altitude. As part of its mission, the satellite also receives, processes and retransmits data from free-floating balloons and remote observation stations around the globe.

NOAA 8, launched on 28 March 1983, performed satisfactorily until 12 June 1984 when difficulties arose with its master clock. Complete disruption of the attitude control system occurred on 30 June, leaving the spacecraft tumbling and unable to relay signals to Earth effectively.

CHINA DBS DEPOSIT

NASA has received $200,000 'earnest money' from the Chinese Broadcasting Satellite Corp. for launch reservations in January and September 1988 for two domestic direct broadcast satellites.

On 29 October 1984 NASA Administrator James Beggs met senior members of a CBSC delegation in the US to discuss the procurement of satellits and launch services. The group also observed the launch of Shuttle Mision 51A and visited the Johnson Space Center in Houston.

OTHER NEWS

SPACE STATION STUDY

Lockheed is working under a $1 million contract from NASA to define ways to improve crew performance aboard the Space Station. During the nine-month study, Lockheed will design several crew facilities and will identify operations and training requirements needed to support crew activities.

'Early understanding of how men and women will live and work aboard a Space Station is an essential ingredient in defining how the facility should be developed,' says Bob Marcellini, Director of Space Station Programs at Lockheed.

SPACE STATION BIDS

NASA has received 13 proposals from US industry for definition and preliminary design of the Space Station in response to a Request for Proposal issued on 14 September 1984. The deadline was 15 November.

The request contained four 'work packages' covering definition and preliminary design (Phase B) of Space Station elements. NASA plans to let competing contracts for each of the work packages by 1 April.

This listing below includes the members of each team, with the leaders given first:

Work Package One: Marshall Space Flight Center. Definition and preliminary design of pressurised 'common modules' with appropriate systems for use as laboratories, living areas and logistic transport; environmental control and propulsive systems; plan for equipping a module as a laboratory and additional ones as logistics modules; and plan accommodations for orbital manoeuvring and orbital transfer vehicles.

Boeing-Teledyne Brown Engineering; General Electric; Vought; OAO; Thermacore; Garrett; Hamilton Standard; Life Systems; Lockheed, Umpqua; Perkin-Elmer; Fairchild; Aerojet; Rocketdyne; Rocket Research; Eaton; Sundstrand; Westinghouse; Rockwell Autonetics; TRW; Computer Tech Associates; Hughes; Telephonics; Camus.

General Dynamics-Grumman; Hamilton Standard; Life Systems; Ford Aerospace; TRW; Ball Aerospace; Computer

Sciences; Otha C. Jean & Associates; Aerojet, Honeywell; RCS; Rocketdyne; SPAR Aerospace; Sperry; Telephonics.

Martin Marietta-McDonnell Douglas Technical Services; Hamilton Standard, Honeywell; Hughes; Hercules; Wyle Labs.

Work Package Two: Johnson Space Center. Definition and preliminary design of the structural framework to which the various elements of the Space Station will be attached; interface between the station and the Shuttle; mechanisms such as the Remote Manipulator Systems; attitude control, thermal control, communications and data management systems; plan for equipping a module with sleeping quarters, wardroom and galley; and plan for extravehicular activity (EVA).

Lockheed-TRW; Bendix; Hughes.

McDonnell Douglas - IBM; Honeywell, RCA; Ball Aerospace; Computer Sciences; Design West; Communications and Data Systems Associates; Eagle Engineering; Essex; Fluor; Ford Aerospace and Communications; Hamilton Standard; ILC Space Systems; SPAR Aerospace; LTV Aerospace and Defense.

Rockwell International - Grumman; Harris; Sperry; Intermetrics; SRI International.

Work Package Three: Goddard Space Flight Center. Definition and preliminary design of the automated free-flying platforms and of provisions to service, maintain and repair the platforms and other free-flying spacecraft; provision for instruments and payloads to be attached externally to the Space Station; and plan for equipping a module as a laboratory.

General Electric - TRW; Essex; Integrated Systems Analysts; Perkin-Elmer; SPAR Aerospace; Teledyne Brown Engineering.

RCA-Lockheed; Ball Aerospace; Computer Sciences.

Work Package Four: Lewis Research Center. Definition and preliminary design of the electrical power generation, conditioning and storage systems.

Garrett-Acurex; Advanco; University of Houston; Electro-Space; Mechanical Technology; Thermo Electron; LTV Aerospace and Defence; EBASCO Services; GA Technologies; Lockheed.

Rocketdyne-Sundstrand; Ford Aerospace and Communication; Harris; Lockheed; Spectralab; Acurex; Georgia Tech.

TRW-General Electric; Grumman; General Dynamics; Perkin-Elmer; United Technology; Merchanical Technology; Life Systems.

Other Proposals:
Natural Energy Systems-ODC, Inc. J.C.
J.C. Gadouy

In addition, the request also requires contractors to study how those elements of the Space Station would change were the station originally man-tended rather than permanently manned. Contractors will also be expected to pay particular attention to recommendations of the NASA Advanced Technology Advisory Committee, which is identifying automation and robotic technologies that could be used.

Following completion of the 18-month definition and preliminary design contracts, NASA intends to move, in 1987, into final design and development. Proposers for the definition and preliminary design phase must have the capability to perform and manage the design, development and test phase (Phase C/D) of their appropriate work packages.

MILESTONES

October 1984

31 Japan's first deep space antenna is completed. It will be used to communicate with the Halley's comet probes, MS-T5 and Planet-A.

November 1984

1 The optics for the Hubble Space Telescope, due for launch in 1986, arrive at Lockheed's plant in California for integration with the rest of the telescope.

4 The Nato 3D communications satellite is launched by the 177th Delta rocket from Florida. No further Deltas are scheduled until mid-1986.

5 The military Shuttle mission originally due for launch on 8 Dec. will carry the first of a new batch of astronauts dedicated to such flights. The four-man NASA crew will be joined on 51C by USAF Major Gary Payton; they will launch a classified satellite. *Challenger's* launch time will not be announced in advance. The flight has been delayed to mid-Jan. from 8 Dec. because of problems with the thermal tiles.

5 A stuck bearing on a scanning mirror has been freed aboard the US GOES 1 weather satellite, launched in 1978.

10 Ariane VII, the second 3 version, successfully orbits the Spacenet 2 and Marecs B2 communications satellites.

16 Shuttle *Discovery* lands at KSC to end the 51A mission after 7 d 23 h 45 m; the first to recover satellites. Westar and Palapa will be returned to the Hughes Co. in California for refurbishment and then relaunch. The insurance owners expect to sell them for $30 million each; NASA was paid $10 million for the rescue.

19 NASA has received 13 proposals from US industry for definition and preliminary design work for the Space Station. Contracts are expected by 1 April.

19 NASA's Johnson Space Center has formed an 'Artificial Intelligence and Information Science Office' in support of the Space Station.

19 Model of BAe Olympus communications satellite, due for 1987 operations, successfully completes thermal testing.

20 All of the Systems aboard the Marecs B2 maritime communications satellite have now been switched on and are working satisfactorily.

26 Giotto, the Halley's comet probe, has completed thermal vacuum testing at the French space agency's facility in Toulouse. Giotto is expected to be shipped to the launch site next April.

26 The Ariane 1 rocket carrying the Halley's comet probe, Giotto, next July will see the first attempt at recovery of the first stage. ESA hopes to be able to reuse some components in future versions, including the liquid-propellant boosters of Ariane 4.

26 Astronauts Crippen and Gardner will pilot the first Shuttle flight from the Californian coast next October.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

By Gordon L. Harris

ALTERNATIVE VIEWS

The continuing struggle by the US Congress to influence, if not to dictate, US space policy took a new direction when the Office of Technology Assessment said there should be no commitment to a Manned Space Station until the country defines long-range goals in outer space. Supposedly non-partisan, OTA depends upon congressional support for its existence and funding. The 1984 election, which gave President Reagan an overwhelming vote of confidence, failed to dislodge the Democratic majority controlling the House of Representatives and OTA.

The office released a pp.230 report on 13 November (one week after election), concluding that potential uses outlined for the $8,000 million station pursued by NASA do not justify the cost and effort. 'Because the nation does not have clearly formulated long-range goals and objectives for its civilian space activities,' the report said, 'proceeding to realize the present NASA space station concept is not likely to result in the facility most appropriate for advancing US interests into the second quarter century of the Space Age.'

Thomas Rogers, OTA consultant, emphasised the study's proposal for a broad public debate on national space objectives. No such debate has ever taken place. President John Kennedy caught the public's imagination in 1961 with his call for manned landings on the Moon without the sanction of prolonged discussion or debate.

Rogers said 'it is most important that the general public play a much broader and active role in articulation of programme goals. What alternatives had the public been provided with? Essentially none. We think that's a shame. NASA may be on the best course, but there is a completely different course that has not been explored or debated.' He added that the $150 million NASA is spending over the next 18 months for Space Station design will be a good investment regardless of Congress' decision on future funding.

The OTA report cited 10 'goals' for consideration ranging from a worldwide disaster warning system to a 'modest human presence' on the Moon. OTA spent two years on its study with an advisory panel of engineers and scientists at the request of Congressional committees.

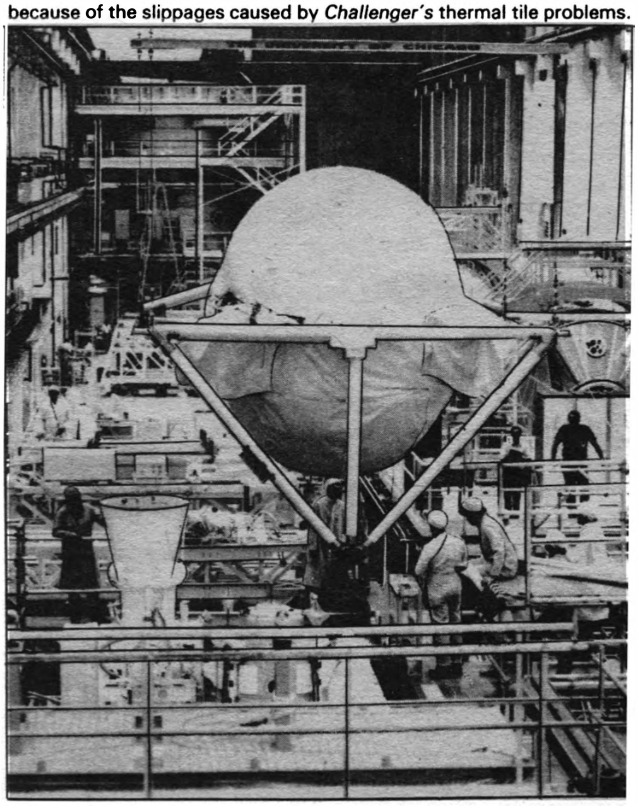
President Reagan directed NASA in January 1984 to develop a station that could be in orbit by the early 1990's. Opponents expect resistance when NASA asks for more money next year.

OTA thinks the National Commission on Space created by Congress last year should take the lead in sponsoring a national debate on space planning. The Commission was an obvious attempt to offset the National Space Council report to the President. A less ambitious orbiting station could be used to store fuel and supplies, launch voyages to the Moon or planets and permit testing new instruments and activities, according to the study.

The report observed that, 'Automated facilities capable of supporting many activities will not be available before 2000 AD even if a large automation program is begun immediately.' As a starting point for debate, OTA suggested reduction of unit cost of space activities, direct public involvement, increased international cooperation, and exploration of the Solar System. The space agency, said OTA, should look at reducing cost by changing procurement methods to encourage investment by foreign governments and private interests.

Some NASA officials were less than pleased by OTA's comparison with the Soviet Salyut, concluding that a US 'Salyut' could be flown for one-third the price tag of NASA's design. 'A USA version that approximates Salyut 7 could be assembled using essentially existing or currently under development technology (Spacelab modules and a service module composed of Eureca or Leasecraft-type power and attitude controls),' the report said. Eureca is the European Retrievable Carrier satellite, while Leasecraft is a commercial orbiter being developed by Fairchild. OTA drew upon a 1982 'minimum cost' Space Station studied by NASA's Marshall Space Flight Center. OTA also cited extended duration Shuttle Orbiters that would sustain a five-man crew for 20-50 days and a free-flying Spacelab with a three-man crew resupplied at 60 to 90-day intervals. MSFC found that a 50-day orbiter could be developed in five to 10 years for $1,500 million. Another $1,000 million would be needed to sustain 12 dedicated 30-day missions. OTA priced its Salyut type at $2,000 million.

The two tonne cosmic ray detector for one of the 12 major astronomical experiments on Spacelab 2 is moved into position. The flight, until recently scheduled for April, might now have to wait until July or later because of the slippages caused by *Challenger's* thermal tile problems.



NASA'S FUTURE PLANS

Some NASA supporters have criticised the agency for failing to define long term goals. The current administrator, James Beggs, silenced critics for a while at least when he predicted that the US would return to the Moon by 2010. His statement came at a symposium conducted by the National Academy of Sciences on lunar bases and space activities in the 21st Century.

Speaking of the lunar goal, Beggs said 'We will do so not only to mine its oxygen rich rock and other resources but to establish an outpost for further exploration and expansion of human activities in the Solar System, in particular on Mars and near-Earth asteroids.' Beggs said that the Space Station of the 1990's will serve as a departure point for lunar exploration.

A little-known report issued by a University of California workshop in mid-1984 urged a 'permanent lunar base to use the Moon as a platform for astronomical, solar and plasma observations and a place to do scientific experiments that cannot be done elsewhere... industrial development is a compelling component of lunar base (to test) our ability to adapt resources of space for our needs in space.

Dr. George Keyworth, science advisor to President Reagan, and Alaska Governor Walter Hickel also addressed the Washington meeting. Keyworth described the Shuttle as 'the beginning of the maturing phase of space technology.' He identified three major questions confronting the nation: 'Are our grand exploration days just beginning, or will we spend our time consolidating our gains, or do a combination of both?' He suggested 'we may have to do both,' cautioning the symposium that we must decide where to go after a Space Station and lunar base exist and what impact they may have on Earth.

A former Interior Secretary, Governor Hickel said that 'as a newcomer to the space programme I was appalled to find out we've dismantled the tools and, more importantly, a collection of minds who built the Saturn moon rocket.'

PAGE RETIRES

George Page, KSC deputy director since June 1982 and launch director for the first three Shuttle missions, has retired from NASA. Page joined the agency in June 1963 as spacecraft test conductor for Gemini; he held the same position during Apollo. Later he served as chief of the spacecraft division for Apollo, Skylab and Apollo Soyuz launch operations, director of expendable vehicle launch operations, director of cargo operations and Shuttle operations director. He received numerous awards for outstanding service.

TAXING ISSUES

Incentives offered to US industry in the form of tax credits, deductions and depreciation do not extend to space - a situation that hinders private enterprise interested in utilising Shuttle missions for profit. Richard Sussman, tax specialist for Fairchild Industries, observed that unless there is a change, it is fair to say that US space-based businesses will never get off the ground. Fairchild and McDonnell Douglas are trying to promote orbiting laboratories and are lining up prospective clients. The Internal Revenue Service insists that firms can claim only deductions and credits for investments whose 'physical location' lies within the US borders. Thus Sussman says Fairchild's proposed $80 million Leasecraft orbiting factory would be subject to heavy taxation: no credit on new equipment (10% is allowed on Earth). Nor do space stations qualify for the five-year depreciation allowed on equipment. The question of how to treat products developed in space has not been resolved. The Commerce Department thinks they would be imports and subject to duties, and when NASA carries a commercial item free of charge in a Shuttle, IRS considers the owner has received taxable income. The next Congress will take up these issues.

NEW SHUTTLE PASSENGER

NASA has invited US Senator Jake Garn (Utah Republican) to become the first public official to fly in a Shuttle. A retired military pilot, Garn expects to board an early mission as a payload specialist and will undergo training for his duties.

LAUNCH ATTENDANCE

Shuttle launches are becoming so routine that fewer people are accepting NASA's invitations to witness the events at the Kennedy Space Center. *Discovery's* liftoff on 8 November 1984, the 14th Shuttle flight, brought about 200 guests, most of them employed by firms that built the cargo. Arnold Richman, chief of visitor services, issued 1,500 passes admitting private vehicles to a vantage point on the causeway linking KSC with Cape Canaveral. The total was less than a third of normal. 'With so many launches people are starting to pick and choose which they want to attend,' Richman said.

SHUTTLE FACILITY

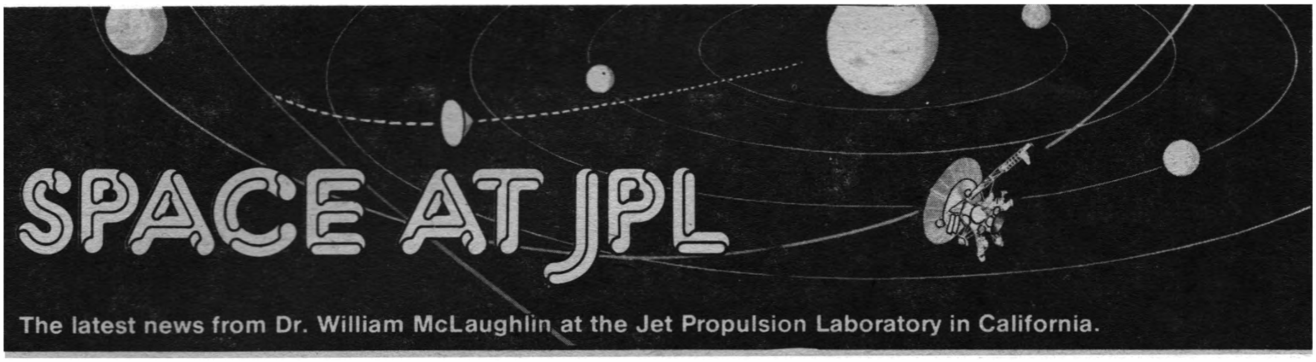
A new facility will be constructed at KSC by the Doster Construction Co., at a cost of $7,500 million. The new structure will include an airlock, high bay and clean room for processing hazardous Shuttle payloads.

LAUNCHER SERVICES

The Kennedy Space Center awarded the Computer Sciences Corp. an extension of a contract valued at $2 million to continue support work at the launch base until 30 September 1985. CSC furnishes instrumentation and computing services for the testing and launching of Delta, Atlas Centaur and Shuttle/Centaur vehicles.

DELTA LAUNCH

One of the few remaining Delta rockets carried the NATO 3D communications satellite off Pad 17A on 4 November. Originally scheduled for 18 October, the event was postponed to permit repair and replacement of four travelling wave tube amplifiers in the satellite.



HYPERVELOCITY IMPACT

One of the central achievements of the programme of Solar System exploration begun by NASA over 20 years ago has been the enormous increase in our knowledge of planetary structure. The most obvious area is the geologic processes revealed by surface imaging of, for example, volcanoes on Io, water-sculpted features on Mars and impact craters on terrestrial type bodies.

Knowledge of structural conditions below the surface, down through the planetary core, has also been augmented by space experiments. Observation of surface conditions and careful measurement of a planetary gravity field provide data for theoreticians to infer the state of the deep interior of a planet.

The pressures in the core are so great, however, that the attempt to model this region runs into the problem that very little is known about how common materials behave under extreme pressures. The advanced-concept review for this month looks at a proposed laboratory experiment to gain additional information on the behaviour of materials under high pressures. It seems fitting that this experiment should itself be conducted in a space laboratory.

Dr. Thomas Ahrens is a professor of geophysics at Caltech and performs hypervelocity impact experiments in his terrestrial laboratory (the Lindhurst Laboratory of Experimental Geophysics) to study materials under high pressure. The larger of two 'guns' in the laboratory is capable of accelerating a 15 g projectile to 7 km/s (almost low Earth orbital velocity!) over a length of some 10 m. As the projectile hits the target plate at the end of the evacuated gun, a collection of electronic sensors measures the effects associated with the brief period of high pressure: about 10^{-8} sec. The pressure during this instant reaches some 4 megabars (a megabar is approximately equal to one million Earth atmospheres), which is close to the pressure at the centre of the Earth.

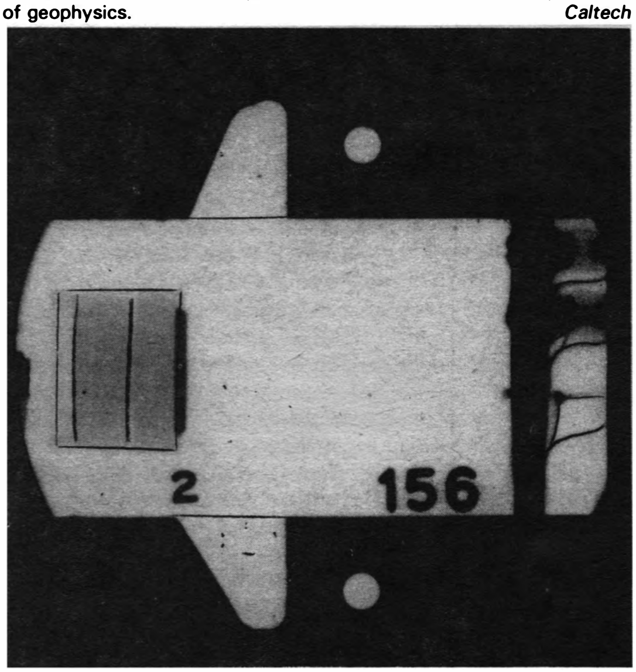
In order to extend these laboratory results to longer times and higher pressures, Ahrens has conceived an elegant experiment which would slam together two objects orbiting the Earth in opposite directions and measure the effects on the participating materials. The velocity of impact, approximately 15 km/s, would be twice orbital velocity and the pressure would reach an intense 20 megabars for the 'long' period of 10^{-4} sec. For comparison, pressure at the centre of Jupiter is about 30 megabars and at the centre of Saturn reaches some 20 megabars.

The experiment draws upon near-Earth resources in an efficient fashion: employing the high energy of orbiting objects and the vacuum of space, resources that are obtained only with considerable effort in terrestrial impact experiments.

A second experimental set up for impact studies in space would take advantage of the near vacuum and zero gravity to build a large 'gun.' With this device, higher velocities could be achieved than on Earth due to the increased size of the mechanism, allowing continuous acceleration of the projectile over a longer period. Ahrens speculates that velocities up to 100 km/s might be produced in this fashion, yielding pressures on the order of hundreds to thousands of megabars.

What material phases might be produced under extremes of pressure? A metallic version of diamond could be generated or, less likely but possible, metallic hydrogen. Not only scientific data would result from such experiments; prototypes of space manufacturing operations could be tested, for example, the high pressure phases of titanium dioxide. Thermodynamic considerations indicate that high pressure phases of materials tend to be harder and more temperature resistant than ordinary matter. Thus, a programme screening various materials could be expected to yield additional candidates for industrial use.

In this X-ray photograph a projectile is shown hurtling at 6.22 km/s towards a hypervelocity impact with an instrumented target. Impact will occur in less than 10 micro seconds. The dark flyer plate of the projectile lies directly above the numeral "2" in the photograph and is composed of tantalum. The remainder of the projectile (not as dark) is of plastic; a very light vertical stripe in its centre indicates that it is starting to lose some structural integrity under the stress of flight at near-orbital speed. This photograph was taken in a gas gun at Caltech's Lindhurst Laboratory of Geophysics. The experiment, to study the behaviour of materials under high pressures such as occur in planetary interiors, was under the supervision of Dr. Thomas Ahrens, professor of geophysics. *Caltech*



Ahrens has received NASA funding in the past to develop the design for his orbiting hypervelocity impact experiment (though no work is currently in progress). If the concept should mature into an actual project, one can imagine a mission scenario that might result:

"It is December of 1994 and an impactor vehicle, originally carried into orbit on a Shuttle launched from Vandenberg site in California, speeds south at 7½ km/s at an altitude of 500 km above San Francisco.

"At the same time the larger target vehicle moves in a northerly direction, passing over Los Angeles. It will meet the impactor vehicle in less than one minute.

"In these final seconds before collision laser beams explore the regions between the two vehicles and small trajectory corrections are made to insure that the collision will be head on.

"At the last microsecond before contact the impactor plate ('the hammer') is separated from the target sample by little more than a centimetre of space. As this distance closes to zero the impactor plate begins to crush the 1 m diameter sample against the anvil on which it has been mounted.

"The wave of compression begins its leisurely march across the sample, taking hundreds of microseconds to finish the trek. During this time the flattening sample is subjected to pressures ussually borne only by material inside stars and planets; its molecules are rudely shoved together, penetrating at times their neighbours' electrically repulsive cores. Phase changes wink on and new crystal patterns are formed. The material's electrical conductivity changes. Infrared and visible photons are squeezed out.

"Nearby, on a dynamically isolated observing platform, high-speed cameras record the flow of matter and a spectrometer monitors the flow of photons. The sample is probed by flashing X-rays to measure its density.

"The momentum trap behind the sample is vaporised and expands into free space, arresting the violence of the event and preserving the target vehicle's integrity.

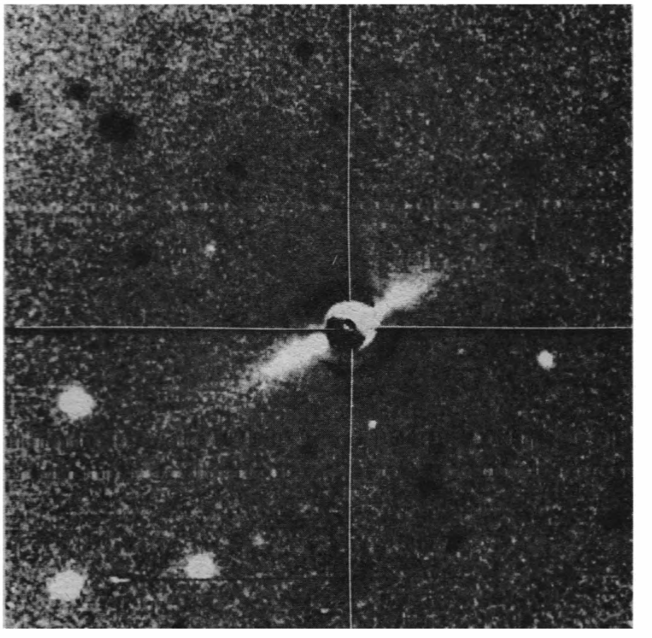
"Information from the monitors is fed back to the ground through NASA's Tracking and Data Relay Satellite (TDRS), enabling analysts to complete the equation of state for the material, applicable to previously inaccessible conditions.

"The target vehicle with its load of samples continues its movement toward the north pole. Ground controllers activate another impactor stored in orbit and begin to manoeuvre it into position for collision with a second sample."

POSSIBLE NEW SOLAR SYSTEM

For the first time, a photograph has been taken that shows a disc of solid material orbiting another star. Dr Bradford Smith (University of Arizona) and Dr. Richard Terrile (Jet Propulsion Laboratory) have photographed a vast swarm of particles orbiting the star Beta Pictoris, 50 light years from Earth. There is some evidence to suggest that planets could have formed. The brightness of the star seen through the disc indicates that the innermost particles of the disc might have been swept away.

Beta Pictoria was distinguished during the 1983 survey of the sky by the Infrared Astronomical Satellite (IRAS) as the star possessing the largest infrared excess (see January 1985's 'Space at JPL') - an indicator of the possible existence of cool, circumstellar material. When, as a result, Smith and Terrile turned the 2.5 m telescope of the Las Campanas Observatory in Chile on Beta Pictoris they were able to detect a flattened disc extending some



This image of particles orbiting the star Beta Pictoris was taken with the 2.5 m telescope at Las Campanas Observatory in Chile The material is in the form of a disc about the star and is seen approximately edge on. The image, in visible light, was taken because of indications of possible material obtained by the Infrared Astronomical Satellite in 1983. *NASA/JPL/Las Campanas*

60 thousand milliom km outwards. The particles probably range in size from tiny grains a few microns in diameter to larger particles several kilometres across. It is not possible to determine if planets are present other than through indirect indications.

Beta Pictoris is a faint, fourth-magnitude star in the constellation Pictor, primarily visible from the southern hemisphere, which makes the Chile location ideal for observing it. Las Campanas Observatory is operated by the Carnegie Institution in Washington.

A charge-coupled device (CCD) and coronagraph were employed along with the reflecting telescope. The CCD makes possible the detection of very faint objects, while the coronagraph helps to block out the otherwise overpowering light from Beta Pictoris. As the name indicates, coronagraphs were originally devised to block out sunlight, allowing astronomers to view the faint corona surrounding the the solar disc without waiting for a natural solar eclipse. The image of the Beta Pictoris system was extensively computer processed at the University of Arizona and JPL. The total observing and processing task was funded by the University and by NASA's Office of Space Science Applications.

NSCAT STARTS UP

The NASA Scatterometer (NSCAT) project has been formed at JPL. The scatterometer is an instrument that will be built for the purpose of flying aboard a satellite to make measurements of wind direction and speed over the surface of the world's oceans. In addition to constructing the instrument, the project is responsible for processing the return data.

The NSCAT Project is NASA's part of a multi-agency programme for which the US Navy has primary responsibility. The Navy Remote Ocean Sensing System (N-ROSS) programme includes participation by the US Air Force and the National Oceanic and Atmospheric Administration (NOAA), in addition to NASA.

A launch date of June 1989 is planned for the N-ROSS satellite at the beginning of its three-year mission; it will be carried aloft from Vandenberg aboard a Titan II launch vehicle of the US Air Force. The satellite, which will carry three other instruments, is planned to be an existing NOAA-D weather satellite bus supplied by NOAA. This vehicle will be modified to be compatible with the telemetry, tracking and command capabilities of the Defense Meteorological Satellite Program's (DMSP) network of ground stations which will track the satellite and forward the data to the processing centres.

The satellite will be placed into a circular orbit 830 km high at an inclination of 98.7°, resulting in a Sun-sychronous orbit.

The scatterometer operates by putting 110 W of power sequentially into six antennae, radiating microwaves on the ocean's surface at a frequency of 14.0 GHz, detecting the returned energy and deducing from it the wind vector just above the surface. The amount of energy returned to the satellite is a mere 10^{-16} W, a reduction of some 18 orders of magnitude over the output power.

The objectives of the NSCAT project are to provide wind vector data for research in oceanography and meteorology and to advance the state of scatterometer instrument development. The resolution of the instrument will result in the determination of the average wind direction and speed over an area only 25 km on a side. The satellite will be employed using fast Fourier transform (FFT) techniques to produce a much lower data rate than if the raw data were transmitted. The instrument will have a mass of about 160 kg and consume a total of 240 W of power.

Scientific announcements of opportunity are scheduled to be issued by NASA this year and will result in the selection of a Science Working Team (SWT) for the project. Processed data will be received by the individuals on the SWT within two weeks after being received at JPL. Other users of data will be in the US Navy, for operational meteorological purposes, and NOAA which will distribute products to the general community of users. Data will also be sent to the Pilot Ocean Data System (PODS), described in the February 1984 edition of 'Space at JPL,' for final archiving and further distribution.

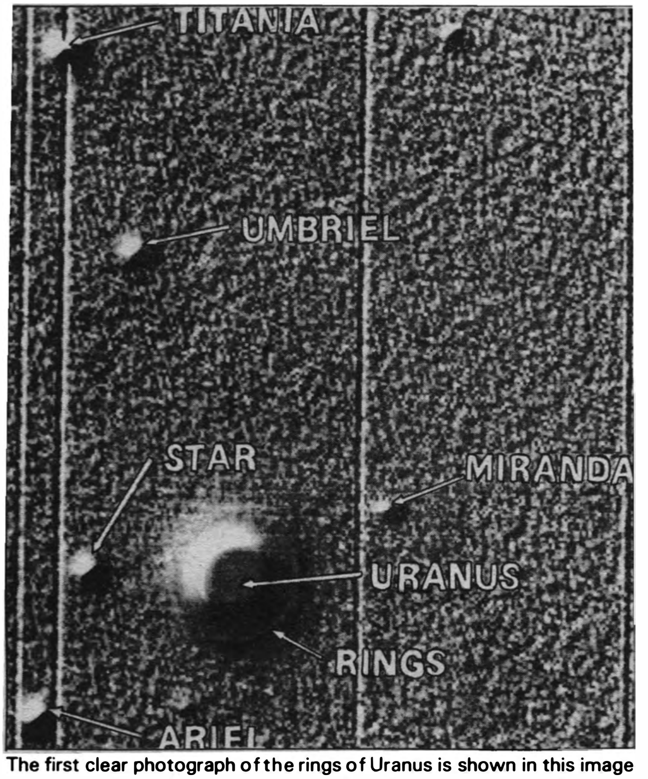
The heritage of NSCAT goes back to the 1978 Seasat proof-of-concept mission which carried a scatterometer as one of its five remote sensing ocean experiments. The Seasat instrument's resolution was only 50 km, and the data were much harder to reduce than those that will be collected by NSCAT because Seasat only carried four scatterometer antennae.

The manager of the NSCAT project is Benn Martin, Dr. Fuk Li is the Project Engineer, and Dr. Michael Freilich is the Project Scientist. NSCAT is managed by JPL for NASA's Office of Space Science and Applications; Bill Townsend is the NASA Programme Manager.

URANIAN RINGS

Dr. Richard Terile of JPL and Dr. Bradford Smith of the University of Arizona have obtained the clearest images to date of the rings of Uranus using the 2.5 m reflector at the Las Capanas Observatory. These two astronomers used the same instrument to record some of the best images of Neptune ever taken, as reported in the November 1984 edition of this column, as well as the Beta Pictoris achievement just discussed.

The pole of Uranus, seeming to have fallen 90° from its 'proper' orientation perpendicular to the ecliptic, currently presents a full, face-on view of the rings and satellites to observers on Earth. But the pole points in a nearly-



The first clear photograph of the rings of Uranus is shown in this image taken with the 2.5 m telescope in Chile. The plane of the rings lies almost entirely in the plane of the image. Most of the light from the planetary disc was blocked off with an occulting device.
NASA/JPL/Las Campanas

constant direction in space as the planet revolves about the Sun every 84 years. So, in a quarter of an orbital period, or about 20 years, the rings will go from being nearly face-on to Earth, as they are now, to nearly edge-on.

Since the five Uranian satellites, as well as the rings, all lie in the equatorial plane of the planet, these objects are laid out for our inspection like grapes on a plate, as the Terrile and Smith image shows. The appearance of the system has also been likened to a bull's-eye which will be pierced by the incoming Voyager 2 spacecraft in January 1986 (but not right in the centre of the target, where the planet lies!). See the illustration in the March 1984 edition of this column for depiction of the relevant geometry of Voyager's approach to Uranus.

The key to the success of the Smith-Terrile image lay in using a very sensitive charge-coupled device (CCD) with the telescope and, at the same time, blocking out the overpowering light from the main body of the planet. The blocking process was not perfectly centred as one can see light from Uranus leaking around the upper left quadrant of the coronagraph device. The vertical lines in the image are due to minor defects in the detector.

The rings of Uranus, discovered in 1977, are among the darkest objects in the Solar System, reflecting only about 2% of the incident sunlight. A paper written a few years ago on the subject in the journal *Science* told it all with its descriptive title: "Uranus: The Rings are Black."

The Uranuan rings also differ from those circling Jupiter and Saturn in that they are nine in number and each is very narrow. The widest one, the so-called epsilon ring, has an average with of about 50 km. One objective of the Voyager exploration will be to try to determine the mechanism that produces such narrow rings. A possibility, as suggested by Voyager images in 1980 and 1981 of the F-ring of Saturn, is that small, shepherding satellites are confining the ring material to narrow zones.

Montreal, Quebec, Canada is shown in this image acquired by the Shuttle Imaging Radar-B (SIR-B) on 7 October 1984, as Shuttle *Challenger* flew over the overcast region. In addition to urban and river features, note the cultivated fields which display long, strip-like patterns typical of French subdivisions of land, as seen in France and some areas of Louisiana settled by the French. *NASA/JPL*

SHUTTLE IMAGING RADAR

The Shuttle Imaging Radar-B (SIR-B) was flown aboard the Shuttle *Challenger* last October and returned useful data despite problems with a Shuttle data link. The SIR-B instrument belongs to the family of synthetic aperture radars. A predecessor, SIR-A, was flown on Shuttle *Columbia* in November 1981 (see 'Space at JPL' in the September-October 1982 issue), and a synthetic aperture radar will be used on the 1988 Venus Radar Mapper mission.

A mechanical problem developed with *Challenger's* antenna, used for transferring high-rate data to the geostationary Tracking and Data Relay Satellite (TDRS) for subsequent relay to the ground. The antenna could not be pointed to TDRS, thus the whole Shuttle had to be positioned so that the immobilised antenna could be properly directed to effect data transfer. During these periods, the radar antenna of SIR-B, used in the imaging process, was not pointed towards its observational targets on the ground and data collection was necesarily interrupted.

Henry Harris of JPL, the Mission Design Manager for SIR-B, and his team had to replan the radar portion of the mission to accommodate these periods of data-collection outage in the Shuttle's timeline. Their basic technique was to employ microcomputers to edit the original mission plan into a form compatible with the new constraints.

Harris' team had learned the value of flexibility and real-time response during the SIR-A experiment and had built a system centred around six microcomputers at the Mission Control Center in NASA's Johnson Space Center. Functionally, the micros were deployed to provide a mission planning station for assessing, for example, the effect of changes in the Shuttle's trajectory; a science planning station at which members of the SIR-B science team could evaluate new strategies; terminals for the display of telemetered data such as signal strength and the temperature of the radar; and a station to hook together all of the other stations into a unified operating system.

The product resulting from the mission planning activity was a command file that was given to the Payload Commander and, after suitable checking, uplinked to *Challenger* for execution. The commands pointed the radar instrument at the desired targets at the correct times for data collection. Orientation of the Shuttle for data transmission to TDRS was accomplished by the astronauts using an onboard computer to calculate the time-varying pointing vector from *Challenger* to TDRS.

Good coordination among the astronauts, ground controllers at Houston, and the mission deisgn team yielded an implementation of approximately 17% of the original mission plan, under difficult conditions. The coordination was facilitated by several mission simulations at Houston, the last one of which the astronauts participated in.

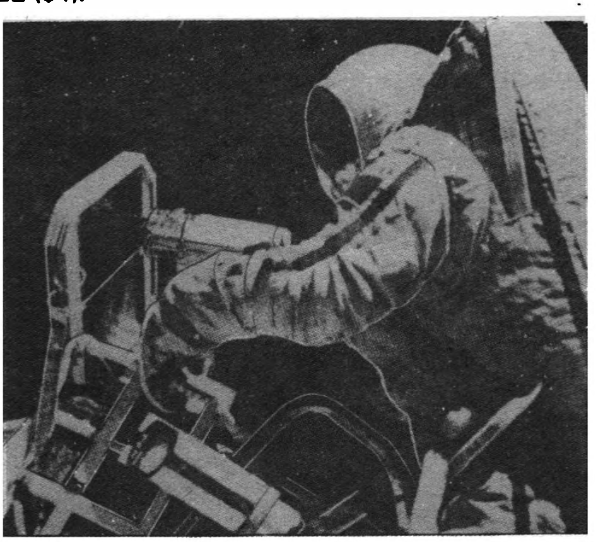
The SIR-B task manager is Edward Cargo and Dr. Charles Elachi is the Principal Investigator. Harris' design team consists of Joan Pojman, Mark Bergam and Su Kim, with software support from Laboratory Microsystems of Los Angeles.

JBIS

The February 1985 issue of *JBIS* is devoted to 'Space chronicle, which includes the following papers:

1. "Spacesuit Development - The American Experience," by K.T. Wilson
2. "US Military Satellites, 1983," by Anthony Kendon
3. "The Flight of Able and Baker," by J.W. Powell
4. "The Soviet Venera Programme," by P.S. Clark.

Copies of the issue are available at a cost of £2 ($4) each, post free from The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. The May 1984, August 1983 and April 1983 'Space Chronicle' issues of *JBIS* are still available at a cost of £2 ($4).



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When ordering, please indicate membership grade and allow six weeks for delivery. Provision for ordering these certificates also appears on the 1985 subscription renewal form.

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

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A NEW EYE ON THE UNIVERSE

By Dr. J.J. Burger *

The Hubble Space Telescope is one of the most ambitious space science programmes ever undertaken. With its 2.4 m primary mirror and extremely fine pointing accuracy, it will dominate astronomical research for the remainder of the century.

Introduction

NASA began Space Telescope studies in 1971 and in 1975 the European Space Agency began its involvement. Approval for the project by the US Congress was obtained in 1976 and in the same year a 15% participation was approved by the ESA Council. Implementation of the project started in 1977 and launch by the Shuttle into a 500 km orbit is scheduled for 1986. Telescope operations are planned to extend over at least 15 years, to be achieved by in-orbit maintenance and, if necessary, on-ground refurbishment. Communications will be through the TDRSS system from a dedicated Space Telescope Operations Control Center at the Goddard Space Flight Center; a dedicated Space Telescope Science Institute has also been established to guide the observational programme.

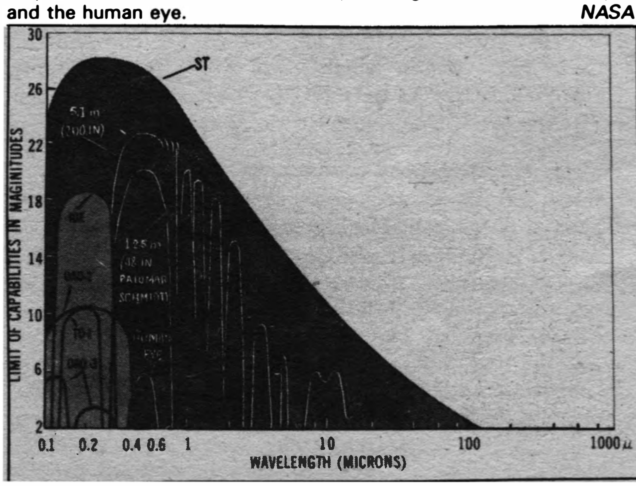
Scientific Objectives

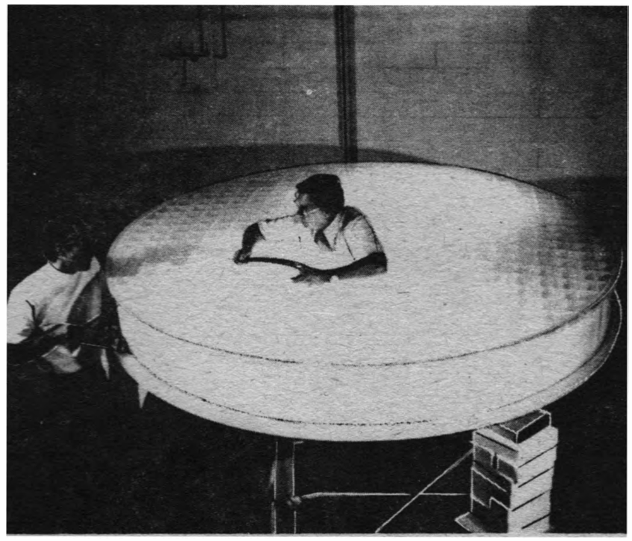
Astronomical observations from the Earth's surface are limited because the atmosphere scatters light, which limits the angular resolution and sets a lower limit on the faintness of observable objects. The Hubble Space Telescope is designed to improve the best ground-based angular resolution by at least a factor of seven and to allow us to see objects 50 times fainter. This implies that we will be able to see objects 10,000 to 15,000 million light years away - close to the edge of the observable Universe. This means we will be able to examine a volume of space 350 times greater than that presently accesible.

A second limitation introduced by the atmosphere is the absorption of light at nearly all but the visible wavelengths. A space observatory thus provides access to ultraviolet and infrared radiation, which carries more astronomical information than the visible. Observations

**ESA Project Manager, Space Telescope.*

The imaging capability of the telescope (upper curve) in comparison with other space observatories (OAO: Orbiting Astronomical Observatory; IUE: International Ultraviolet Explorer;) ground-based telescopes and the human eye. *NASA*





The primary mirror prior to coating.

with the new telescope will affect almost every area of astronomy: cosmology, quasars, galaxies, stellar evolution, dynamics of planetary atmospheres, the search for planets around nearby stars and many more.

The Spacecraft

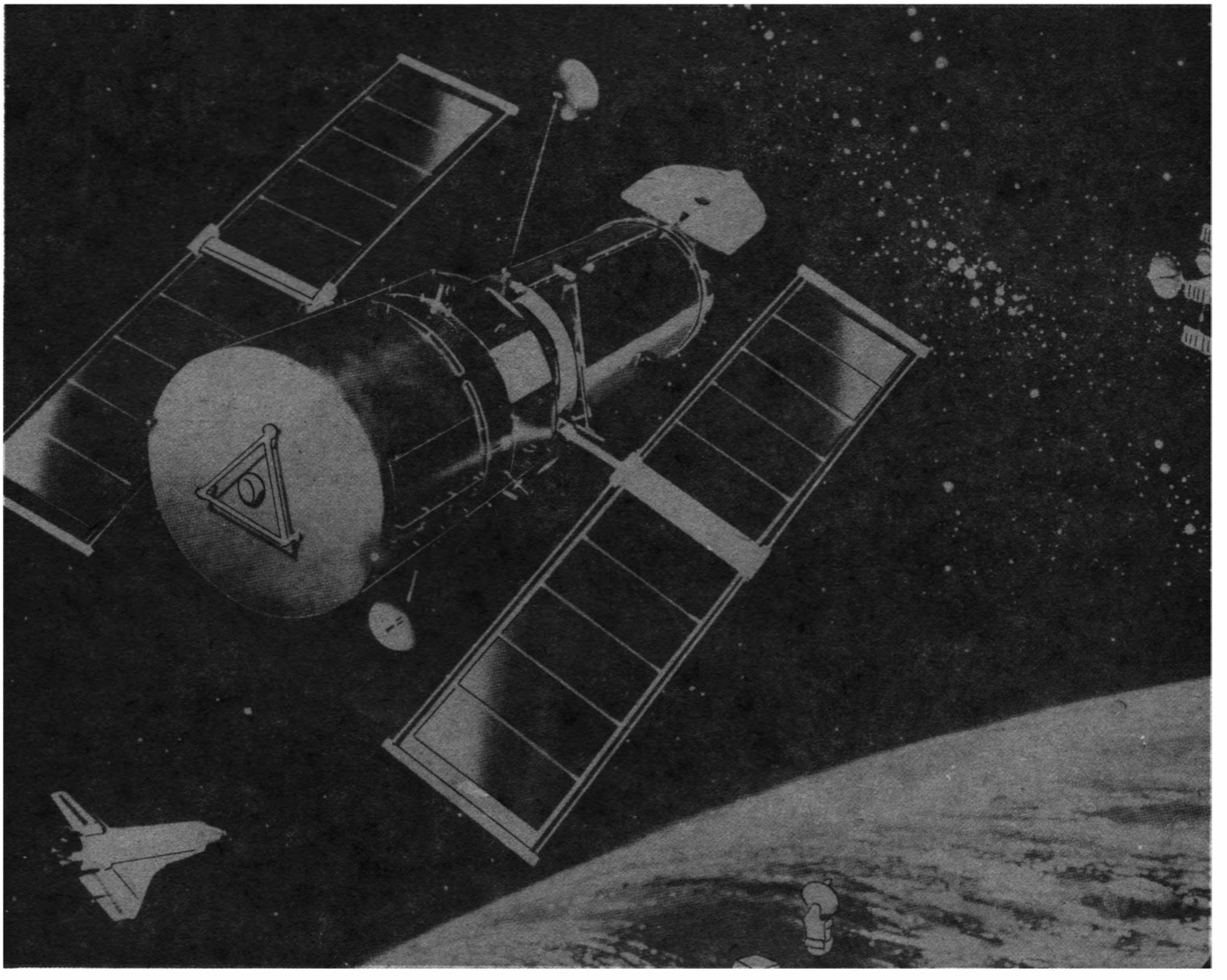
The spacecraft has been designed to fit in the Shuttle's cargo bay for launch. It is 14 m long and 4.5 m in diameter, weighing about 11,000 kg and consisting of three main elements: the Optical Telescope Assembly, the Support Systems Module and the Scientific Instruments with their dedicated Command and Data Handling System. The f/24 Ritchey-Chrétien Cassegrain telescope has a primary mirror of 2.4 m diameter. The optical quality of the mirrors and the mechanical stability of the interconnecting structures have been specified to achieve a diffraction limited performance at 6330 Å. In order to use this optical quality to the full, the attitude control system was specified to have a pointing accuracy of 0.01 arc seconds, with stability over 24 hours better than 7 milliarc seconds. This is equivalent to pointing from Amsterdam at a 1.5 cm diameter circle in Paris.

The image in the focal plane will be used by five scientific instruments and the three fine guidance sensors. Two of these sensors will be used for attitude control; the third can be used for astrometry.

The Optical Telescope Assembly, made by Perkin-Elmer, holds the mirrors rigidly in a precise relationship. The primary is made of ultra-low expansion glass fused to a honeycomb structure to save weight. The optical surface has been polished and coated with an accuracy better than 100 Å over the usable area. This means that if the mirror were scaled up to the size of the USA the largest deviation from the ideal shape would be about 2 cm!

The primary and 30 cm diameter secondary mirror are connected by a carbon fibre truss structure, which meets not only all the typical spacecraft requirements of strength, vibration frequencies and low mass, but also maintains their separation for diffraction limited observations with a pointing stability of 7 milliarc seconds over 16 orbits (half in sunlight, half in eclipse). The secondary mirror can be moved to allow fine focussing in three axes. Actuators at the rear can optimise the shape of the primary mirror in case the allowances made for it being produced in 1 g on Earth were inadequate.

The primary mirror mount is attached to a focal plane structure supporting the five scientific instruments, three



Artist's impression of the Space Telescope in orbit, just launched by the Shuttle and communicating with the ground through the TDRSS system.

fine guidance sensors, three star trackers and six rate gyros. All are designed to allow them to be changed in orbit by astronauts, which requires special latching mechanisms to ensure that the extremely high alignment requirements are met. For structural stability, extensive use is made of carbon fibre and active thermal control systems.

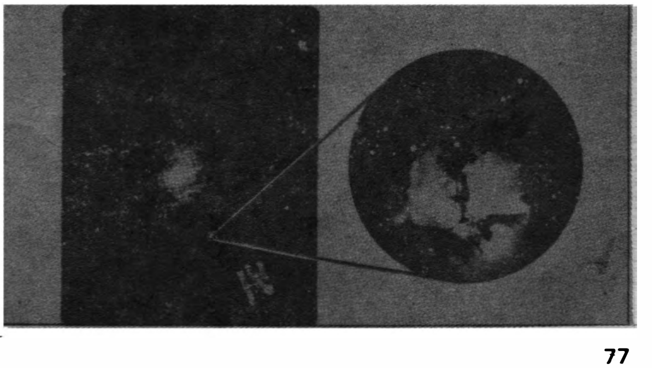
The Support Systems Module is made by Lockheed, who are also responsible for the integrated system design of the complete satellite. The SSM is the main structure of the spacecraft, with interfaces to the Orbiter, light shields, aperture doors (and others to allow astronauts access), communications, data handling, thermal control, power and attitude control systems.

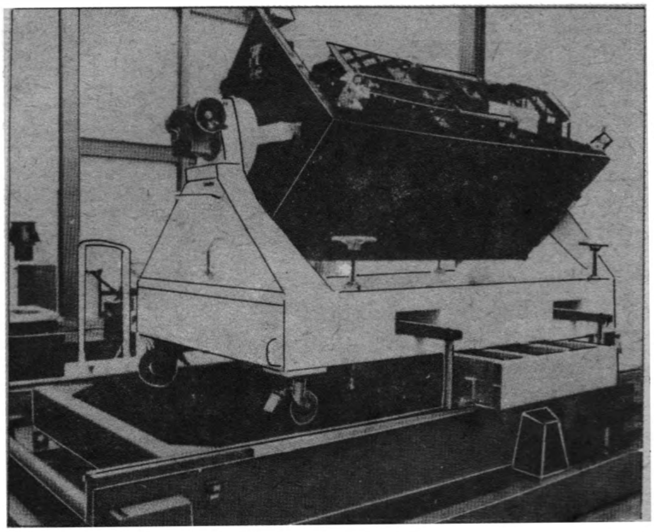
The greatest technical challenge in the SSM is the attitude control system. A computer receives error signals from optical and inertial sensors and computes the required torque moments and commands for four reaction wheels. It also controls magnetic torquers to compensate for the Earth's field. Coarse control is achieved with the aid of star and Sun sensors; fine pointing is done with signals from the fine guidance system looking through the telescope. Rate gyros provide the required inertial signals.

ESA has provided - through British Aerospace - the solar array attached to the SSM with all its mechanisms and associated electronics for deployment and slewing. After two years in orbit it should still provide more than 4,400 W at 34 volts from its 48,760 solar cells (each 2 x 4 cm) spread over two 3 x 12.5 m wings. Designers also had to allow for possible replacement in orbit after five years of operation. At launch (and for landing or maintenance) the array blankets will be rolled up within a diameter of 30 cm. The design also had to avoid unwanted vibration frequencies for the attitude control system to handle.

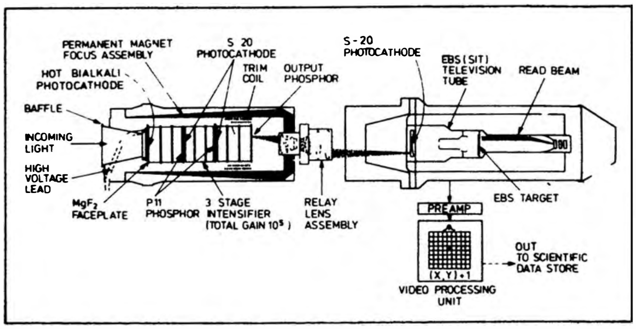
Another challenging requirement was to hold the interactive torque between the arrays and the spacecraft at all times below 0.1 Nm while slewing. In low Earth orbit the blanket temperatures will fluctuate over each orbit from +100°C to −100°C. Over five years and 30,000 orbits a great deal of stress will be suffered by the solar cell interconnectors.

Artist's impression of the gain in spatial resolution achievable with the Space Telescope in comparison with ground based observations.





The flight model Faint Object Camera on its integration trolley. The lower part is the optics compartment; the upper contains electronics.



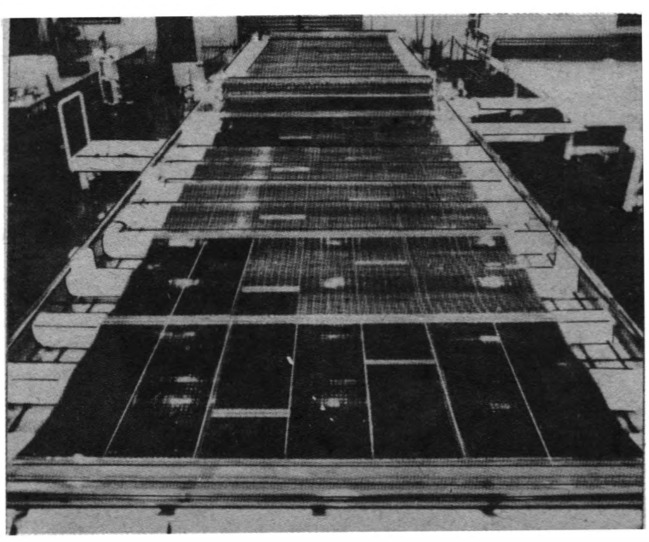
A schematic drawing of the Faint Object Camera's Photon counting detector.

The Scientific Instruments

The Hubble Space Telescope carries five scientific instruments, all interchangable in orbit by new-generation follow-on instruments. The 270 kg Wide Field Camera has its optical axis perpendicular to that of the telescope axis since it is integrated in a radial bay, like the fine guidance sensors, and receives its input light from a 45° pick-off mirror at the centre of the focal plane. It accumulates the image on four CCD detectors (each of 800 x 800 pixels) cooled by heat pipes and an external radiator to −90°C.

The other four instruments have their optical axes roughly parallel to the telescope's axis and are integrated in the four quadrants behind the primary mirror. Their apertures are about three arc minutes off axis, so they have to correct for the off-axis wave front errors. These 'axial' instruments weigh 320 kg and occupy a space of 0.9 x 0.9 x 2.2 m. Included for this first launch are two spectrographs, one optimised for high resolution and one for faint object observations, a high speed photometer and the Faint Object Camera (provided by ESA). All are technically challenging, with the ESA instrument described in more detail below.

The qualification model Solar Array blankets deployed on a water table. Only part of the cells are real, others are dummy.



The Faint Object Camera

The FOC's objective is to exploit the capabilities of the Telescope fully, both in terms of spatial resolution and in reaching the faint object observation limit. To do this, the focal plane image has to be further enlarged and the observations carried out with maximum stability and minimum instrumental noise.

There are two optical relays, one of f/48 and the other of f/96. The optical elements, correcting for the telescope's off-axis distortions, are attached to a carbon fibre optical bench in which a thermal expansion coefficient as low as 10^{-7} has been achieved. To improve the stability further, the optical bench enclosure (the bench itself and the image detectors) has active thermal control - the interface temperatures can vary by more than 50°C but the temperature inside is held to within 1°C.

The image photons are individually counted in the Photon Detector Assembly, consisting of an intensifier tube assembly and lenses coupled to an EBS camera tube. The three stage intensifier, operating at 36,000 V and focussed by a permanent magnet assembly, amplifies the signal from an incoming photon on to the last stage phosphor by a factor of 10^6 and maintains the positional information. The camera tube is operated at 12,000 V and detects the scintillations at the intensifier output. The central x, y coordinates of each light burst is then measured by a video processing unit. Subsequently, the memory cell of a 4 Megabit scientific data store, corresponding to the photon's x, y-position, is incremented by one. The detector's noise level is lower than 10^{-4} counts per pixel per second.

The detector is sensitive from 1200 to 6000 Å and images can be obtained in several formats, ranging from 1024 x 512 pixels to 64 x 64 pixels. Each optical chain also has a large set of selectable filters and polarisers. It is possible to insert an additional small Cassegrain telecope in the f/96 chain to magnify the image further by a factor of three, to f/288. This chain also has a coronograph for observing faint objects near bright sources. The f/48 chain can also be used in a spectrograph mode with spectral resolution of 2000 over the wavelength range 1200 to 5400 Å.

The FOC will be able to observe sources of magnitude +29 or brighter; with neutral density filters a dynamic range of 24 magnitudes is available.

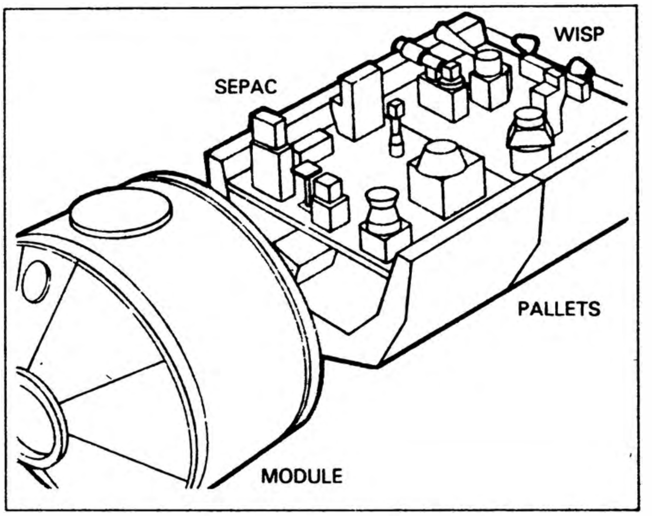
Concluding Remarks

All of the Hubble Space Telescope subsystems have been manufactured and tested, with integration of the complete spacecraft due to start by the end of 1984. The full performance of the complete system cannot be demonstrated on the ground so several months period of in-orbit testing is envisaged. However, exciting images and data are expected even before the telescope reaches full operational status.

FLYING THE SPACE PLASMA LAB

By John Bird

The introduction of the Space Shuttle means that scientists can now fly experiments in space, return them to Earth, make modifications and send them back into orbit. The author discussed just such a project with two of its participants.



General layout of the Space Plasma Lab. The first flight in 1988 will not carry a pressurised module for the astronauts.

Introduction

As part of NASA's plan to fly reusable Spacelab payloads, each dedicated to one discipline, the Space Plasma Laboratory will be used every 18 months. It will employ both active and passive techniques to probe the Earth's environment, as explained to me by Mission Scientist David Reasoner. Originally the first flight was tagged as Spacelab 6 but has now been renamed Space Plasma Lab 1.

Many details of the first flight have already been planned. It is a seven day mission scheduled for June 1988 using Shuttle *Discovery* in a 300 km Sun-synchronous orbit, following instrument delivery to Kennedy Space Center in February of that year.

The laboratory is composed of Spacelab pallets and an igloo in *Discovery's* cargo bay. This payload has a mass of 11,000 kg, of which 3,000 kg is experiments, but a pallet-only configuration is also possible. In either case, Payload Specialist astronauts will be part of the crew. Orientation of the Orbiter will be such that the yaw axis is parallel to the magnetic field lines of the Earth, that is the wings will be at 90 degrees to the Earth's surface.

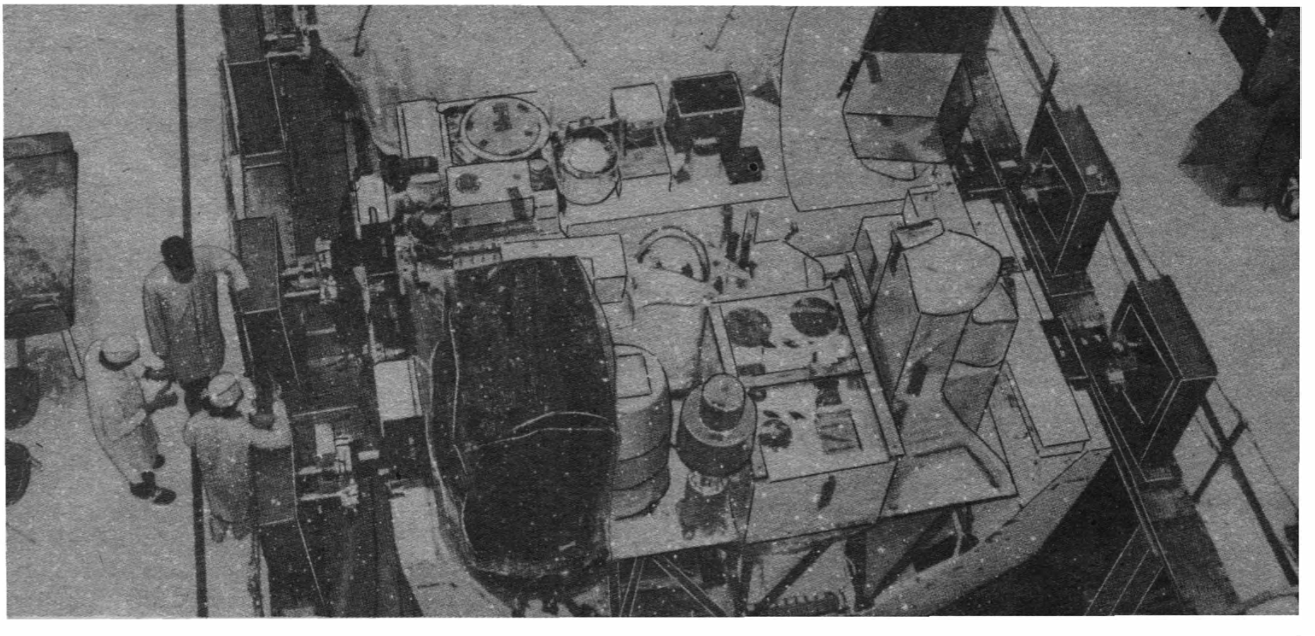
The Experiments

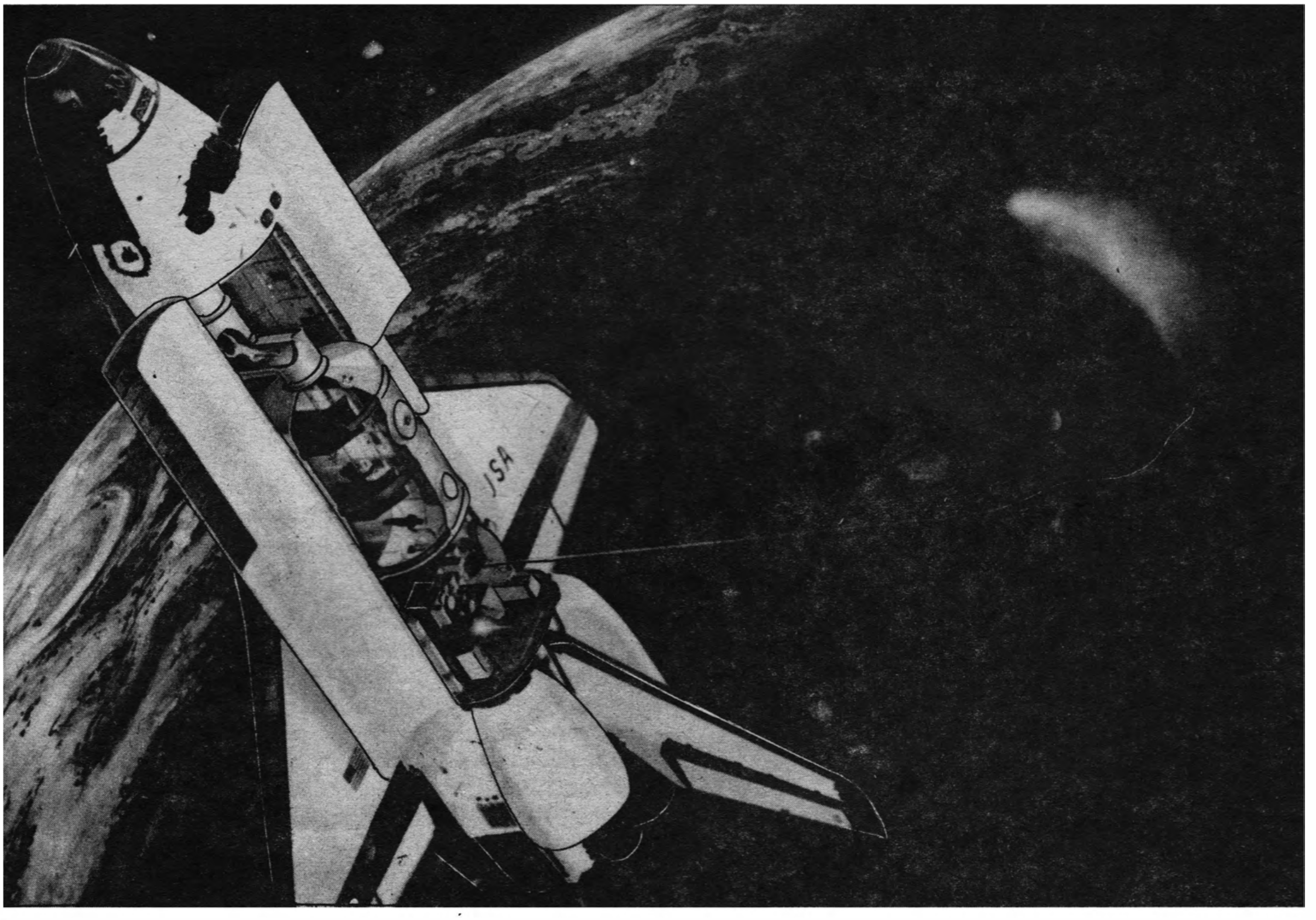
Eleven experiments are planned, falling into three categories: injection of radio waves and particle beams into the atmosphere, experiments deployed by the Remote Manipulator System (including a free flying package), and optical sensing experiments. All involve the study of the thin upper atmosphere which is composed of electrically charged particles, or ions — atoms which have lost electrons. This state of matter is called plasma. On an astronomical scale, plasma is very common — it accounts for more than over 99 per cent of the Universe. For example, our Sun is made of plasma.

In order to study the plasma surrounding the Earth, the experiments of Space Plasma Lab 1 will support each other with measurements, analysing the same phenomena by different techniques. One technique is to transmit radio beams into the upper atmospheric plasma and measure the reflected waves; this will be done by Waves in Space Plasma (WISP) transmitting from 300 Hz to 30 MHz. Different frequencies will travel different distances and, by analysing the reflected beam, the electron density at various altitudes may be determined. The antenna used for this experiment will be 300 m long!

Two of the experiments will inject particle beams into space. The Vehicle Charging and Potential (VCAP) is a pulsed electron gun that will emit a beam for the returning current to be measured. The beam will cause the vehicle to become electrically charged and this can be measured

The pallet of Spacelab 1 carried a multitude of experiments. The Space Plasma Lab concepts shown at the top of the page uses two pallets.





The SEPAC experiment aboard Spacelab 1 was designed to shoot electrons, ions and neutral gas into the atmosphere, creating artificial aurorae.
NASA (artist Seijun Fujita)

with respect to the surrounding plasma. The Space Experiments with Particle Accelerators (SEPAC) was first used on Spacelab 1. Some of the SEPAC experiments will study plasma phenomena near the Orbiter, while some are concentrated at greater distances. Close to the Orbiter, vehicle charge neutralisation and beam plasma physics will be studied. Another interesting experiment involves ejecting a neutral gas from the cargo bay and injecting an electron beam into it. The interaction will create a glow for observation by another experiment. To analyse the atmosphere down to 100 km, the SEPAC Electron Beam Accelerator will inject pulses to probe the ionosphere.

Further investigations of the plasma around the Orbiter will be by experiments deployed on the Remote Manipulator System arm. One is the Theoretical and Experimental Study of Beam Plasma Physics (TEBPP). The effects of beams from other experiments with the plasma will be analysed with an energetic particle spectrometer, pulsed plasma probes, a sweeping plasma wave receiver, an electron probe, a neutral particle density detector and a photometer system. To determine the density and composition of ions, the Energetic Ion Mass Spectrometer (EIMS) includes 11 channel electron multipliers, a retarding potential analyser, an electrostatic analyser and a magnetic analyser.

A Recoverable Plasma Diagnostics Package (RPDP) will be set free by the robot arm to take measurements as far as 100 km from the Orbiter before retrieval. The package could also be used as a tethered satellite, or attached to the arm. Instruments will include an ion mass spectrometer, a triaxial magnetometer, electric and magnetic field sensors, and a composition analyser. Non-recoverable subsatellites called Magnetospheric Multiprobes (MMP) will be set free to simultaneously measure plasma waves.

Four of the instruments in the Space Plasma Lab will use optical methods to observe plasma phenomena. The Wide Angle Michelson Doppler Imaging Interferometer (WAMDII) was developed at York University in Toronto by Dr. Gordon Shepherd. He explained that it is an imaging device to map winds and temperatures as functions of height, latitude and time of day. Particular attention will be paid to winds near aurorae and airglow irregularities. The data will complement results from a Fabry-Perot interferometer on the Dynamics Explorer satellite.

The Atmospheric Emissions Photometric Imaging experiment (AEPI) is a low light level TV camera and a Photon Counting Array. These instruments are mounted for steering on a two-axis gimbal made from a modified Apollo Telescope Mount Star Tracker. The camera has wide angle and telephoto lens to observe beams from other experiments and natural light sources such as aurora and airglow. It was first flown on Spacelab 1.

The Energetic Neutral Atom Precipitation experiment (ENAP) will use five spectrometers to observe visible and ultraviolet emissions from a range of altitudes. Another experiment that will examine light emission at various heights is the Atmospheric Lyman Alpha Emissions experiment (ALAE). Lyman alpha is an ultraviolet spectral line emitted by hydrogen that can reveal the temperature of the hydrogen.

Space Plasma Lab is an evolutionary system designed to be modified as required by scientific objectives, but the basic facility will remain the same. This means that time between flights is minimised, but with maximum scientific return, making it a valuable element of research with the Space Shuttle.

MISSIONS TO SALYUT IN 1985

By Phillip Clark and Rex Hall

It is possible to estimate the landing opportunities for manned missions to Salyut orbital stations [1] and to make predictions for crew compositions. An earlier article looked forward to missions for Salyut 7 in 1984 [2]; this version covers 1985.

Landing Opportunities for 1985

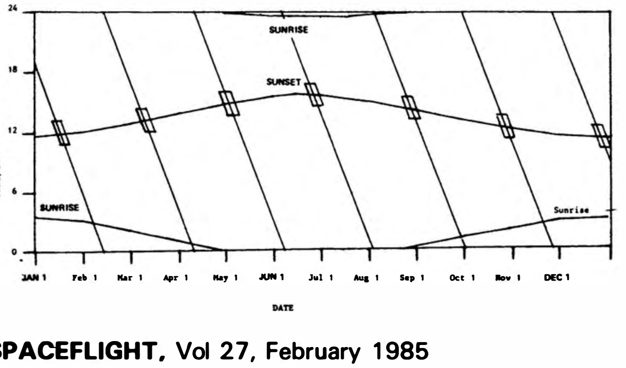
Figure 2 shows the landing opportunities for 1985. The curves show the times of sunrise and sunset over the standard Soyuz landing area, while the sloping straight lines indicate the approximate time of launch or landing for a Soyuz mission to Salyut 7 for any day during the year. A landing 'window' begins when the launch time line crosses the sunset line, the resulting window lasts for about 5 days. During 1985 the nominal landing windows will open on the following dates: 17 January, 10 March, 3 May, 25 June, 1 September, 31 October and 25 December. These are only approximate, and can vary by approximately ± 5 days. This is because Salyut's altitude will vary during the year as a result of orbital decay and manoeuvres, resulting in slight changes in the rate at which the orbit precesses about the Earth.

Mission Scenarios for 1985

It is well-established that the missions to Salyut 7 can be divided into two groups [3]: the 'resident' or long-term crews (which can establish new duration records) and 'visiting' or short-term crews which spend 1-2 weeks in orbit. In 1984 the resident crew launched on Soyuz T-10 established a new duration record of 237 days, and it is possible that during 1985 an attempt might be made to extend this to about nine months. More probably, we can expect to see two medium duration 'resident' crews launched, with missions lasting 4-6 months each. In addition, there should be two visiting missions to Salyut during the year. The two possibilities for 1985 are therefore:-

1. A single nine month mission with two visiting crews;
2. One mission of four months duration flowing with a Cosmos Star module docked with Salyut, followed by a further mission lasting for six months with two visiting crews.

Fig. 2. Salyut 7 landing windows in 1985. The details of the graph are noted in the text. Boxes show the probable limits of the landing windows.



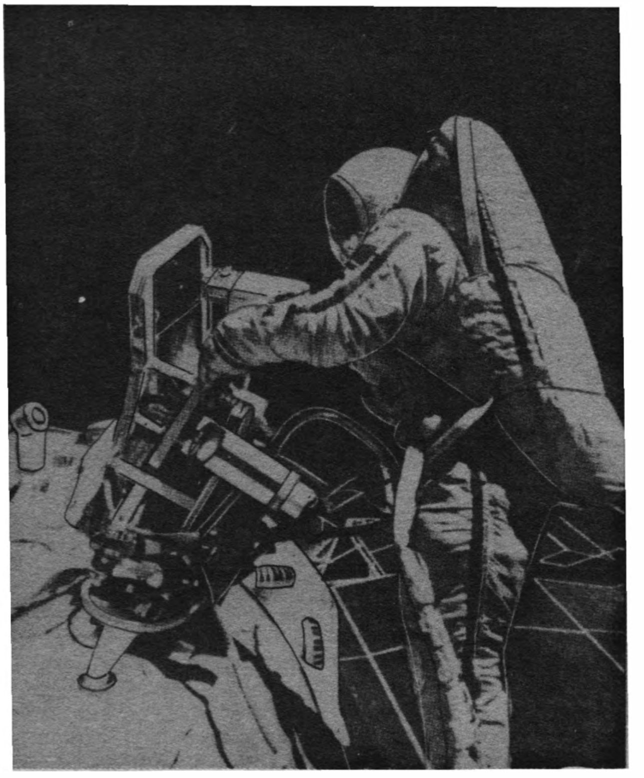


Fig. 1. Svetlana Savitskaya, already a two-time space veteran, could make another flight in 1985. *Novosti*

The flight of Soyuz T-11 in 1984 has shown that the craft can fly for six months in orbit without replacement, and therefore no spacecraft switches would be required for the projected mission in conjunction with a Star module.

Launch Opportunities

The interval between the landing windows is about two months, and therefore missions lasting four or six months will be launched during landing opportunities. If a flight of nine months is planned (or any odd number of months) it will be launched about half-way between landing opportunities. If there is to be a new duration record of nine months, a launch could come in mid-February with a landing in late October or early November. Visiting missions can perhaps be expected in late April and late August.

Alternatively, if medium duration missions are to be

Table 1. List of Active Cosmonauts

Resident
[V.A. Dzhanibekov - Cdr], V.V. Illarianov - Cdr, [Y.V. Malyshev - Cdr], L.I. Popov - Cdr, A.A. Serebrov - FE, [G.M. Strekalov - FE], V.G. Titov - Cdr, [I.P. Volk - FE], ? ? Volkov - Cdr.

Visiting
[A.P. Alexandrov - FE], [O.Y. Atkov - FE], A.N. Beryezovoi - Cdr, V.F. Bykovski - Cdr, A.S. Ivanchenkov - FE, [L.D. Kizim - Cdr], V.V. Kovalenok - Cdr, V.V. Lebedev - FE, V.A. Lyakhov - Cdr, Y.V. Romanenko - Cdr, [V.V. Ryumin - FE], V.P. Savinykh - FE, S.Y. Savitskaya - Cdr?, [V.A. Soloviev - FE], B.V. Volynov - Cdr, "Irena" - FE.

Notes. Names in parentheses are those cosmonauts still active, but who have not been re-cycled to a new assignment. Volkov is a reported new cosmonaut whose initials are not known, while 'Irena' was Savitskaya's female back-up on Soyuz T-7 in 1982, and may have performed the same role for Soyuz T-12 in 1984. Illarianov is a cosmonaut trainee identified at the time of ASTP.

Fig. 3. All three of (from left) Lebedev, Beryzovoi or Savistkaya could fly to Salyut in 1985. *Novosti*

flown, a Soyuz T mission could be launched in January with a Star module docked at the front of Salyut 7, and could return to Earth in early May. A second medium duration mission could follow with a July launch and a late October or late December recovery, and visiting missions launched in mid-August and mid-October. The standard visiting mission (e.g., the Intercosmos visits) lasts for eight days, but the Soyuz T-12 visiting mission in 1984 extended to 12 days.

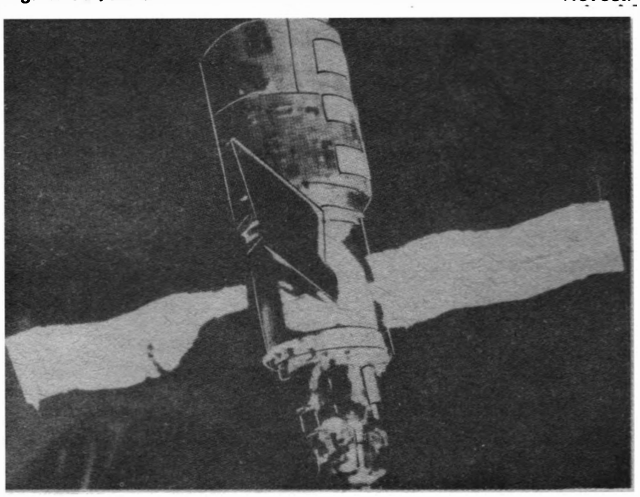
With the requirement for allowing ground crews and tracking ship crews to stand down, it should not be anticipated that one Salyut resident crew will hand the station over to the next resident crew.

In addition to the manned missions, the Progress unmanned craft will take supplies to Salyut to support the crews. Unless there is a change in the Star module design, the Progress craft will not be able to dock with the Salyut/Star module/Soyuz T complex, and therefore Progress will be flown only when there is a Salyut/ Soyuz T complex operating.

Crews for 1985

Table 1 lists all the Soviet cosmonauts who are considered to be still active, but this excludes the many new

Fig. 4. Salyut 7. *Novosti*



cosmonauts who will be identified only when they make their first flights. Based upon the existing flight experience, it has been possible to differentiate between those probably training for residency missions and those training for visiting missions. The status of a second Franco-Soviet manned mission is currently uncertain.

In 1984 N.N. Rukavishnikov indicated that an all-woman team is training for a mission to Salyut 7 in 1985, and this will probably be a visiting crew. Since an experienced cosmonaut is always included in a flight crew, one member must be Svetlana Savitskaya, who has already made two flights. In 1980 four woman began training, and it has been reported that a further group began training in 1982.

The following crew pairings for 1985 seem to be possible:-

Resident Missions

1. Volkov + Serebrov + 1977 'new'
2. Titov + 'new' + 1977 'new'
3. Malyshev + 'new' + 1977 'new'

Visiting Missions

1. Savitskaya + 'Irena' + 1980/82 Woman
2. Romanenko + Savinykh + 'new'
3. Beryezovoi + 'new' + 'new'

The numbers 1977 and 1980/82 indicate the probable cosmonaut groups to which the new cosmonauts belong. The crews are numbered in the order of flight probability for each type of mission. Since each team must have at least one experienced cosmonaut, the back-up team for the Savitskaya crew must include at least one man: this could be Lyakhov with a woman research engineer from 1980/1982 and either a second woman flight engineer or a male flight engineer. It is anticipated that the new mission commanders will be from the 1976 selection.

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SATELLITE SERVICING

By John Bird

A new era has opened in satellite repair and maintenance following the success of April's Shuttle mission to repair the Solar Max satellite in orbit. This ability will be further increased by the Space Station when it becomes operational in ten years' time.

Introduction

Routine maintenance will be done on many satellites at the Space Station by retrieving them with an Orbital Manoeuvering Vehicle or an Orbital Transfer Vehicle (OTV) - the latter for the larger and more distant satellites. The Space Station will be a permanently manned facility in a low orbit with a 28° inclination, supplied by an Orbiter every 90 days with a fresh crew and supplies. In the early 1990's there will be a crew of eight but this will later expand to 16.

There are many advantages in bringing the satellites to the Station to work on them. First of all, more time would be available. On a Shuttle flight there are only a limited number of EVA shifts that can be allocated, whereas a Station could keep the satellite as long as necesary. Secondly, the Shuttle cannot reach satellites in higher orbits, such as those in geosynchronous paths. These *will* be accessible to the Orbital Transfer Vehicle, which will ferry them up and down to the Station.

It is also possible that an inside hangar will be available. Although the Station does not yet have a basic layout, it has been narrowed down to one of three possible configurations. The problem is to define a configuration in which the radiators, solar arrays, docking ports and at least 14 antennae do not interfere with each other.

Satellite Access to the Station

In order to keep some satellites readily accessible they will be held in a 'co-orbiting' configuration, flying in formation with the Station. One of these will be the unmanned Platform, which will be a general purpose support structure with solar arrays, radiators, power distribution systems, communications, etc for a variety of payloads. Other co-orbiters will include observatories such as AXAF and Space Telescope.

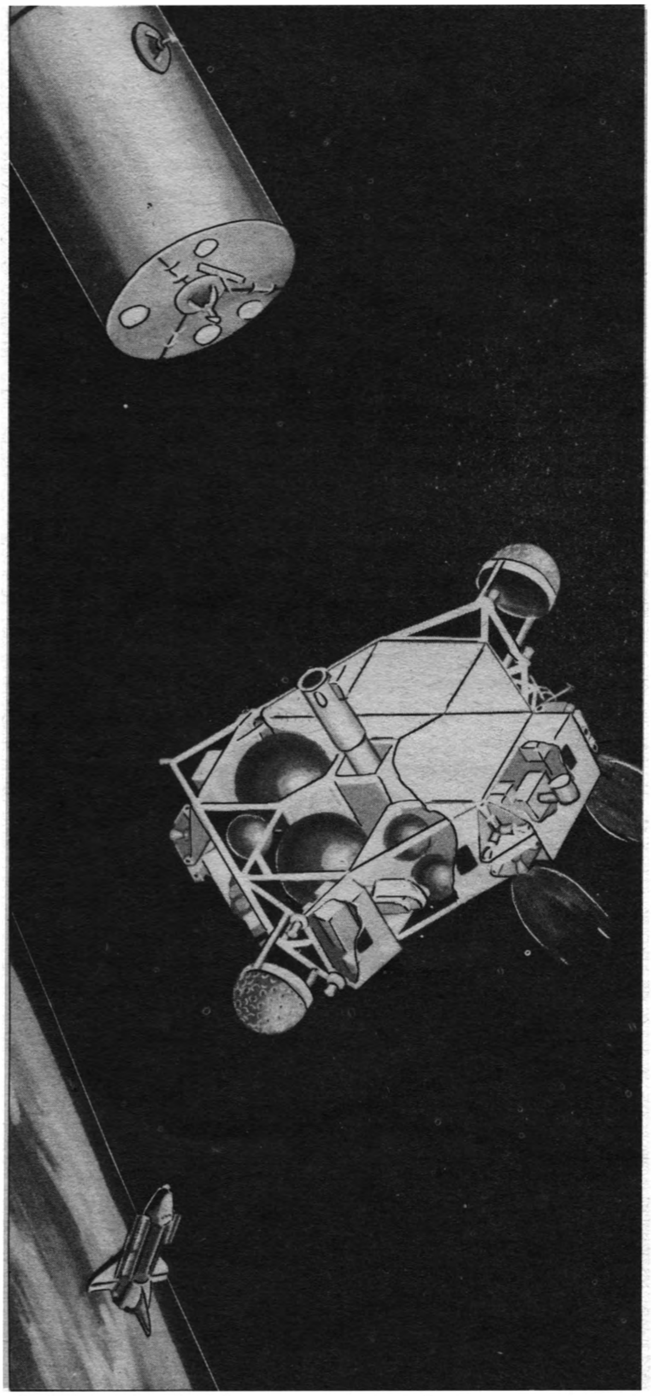
In order to prevent the satellites from drifting into different orbits they must all be at the same altitude as the Space Station. Otherwise, air drag and orbital dynamics would come into play.

There are two modes for flying near the Space Station. One is 'nesting' in which satellites are grouped around a 30 km diameter circle, possibly 500 km from the Station.

The other is 'decaying' in which the satellite is initially about 3 km above the Station and therefore moving slightly slower. By the time it is 1500 km away, its orbit will have started to decay and it will then be moving down to a lower altitude where the orbital velocity is higher. Hence, it would then start to move towards the Station. When it is back underneath the Station, an OMV will dock with it and reboost it to begin the month-long cycle again. A satellite with its own motor would be even simpler to control.

A Typical OMV Retrieval Sequence

The OMV will be an unmanned robotic stage based at the Space Station where, of course, it can be refuelled. Control will be by telepresence, in which an operator uses TV cameras on the OMV to control the stage. Robot arms will be able to replace equipment on the satellites, designed with this in mind. If more extensive work is required, the OMV will bring the satellite back to the Station, put it in a servicing bay and then move back to its berth. Two systems are being considered for the overall design of the bay. One is to attach the satellite directly to the Station, the other is to attach it to a "surrogate cargo bay" which, in turn, is fixed to the Station. The advantage of the latter approach is that the same mechanical fittings used during the satellite's Shuttle launch could be used again. A robot arm similar to the RMS (Shuttle arm) could be included to move astronauts around during repair work, in addition to their Manned Manoeuvering Units.



An artist's concept of an orbital manoeuvring vehicle about to dock with a payload in orbit. OMVs will be used to transfer payloads between orbits that the Shuttle itself cannot reach. Orbital transfer vehicles will handle the larger payloads for higher orbits. *NASA*

By Prof. John Griffith
of Lakehead University,
Ontario, Canada.

THE ORIGIN OF COMETS

Comets are among the oldest heavenly objects known yet attention was focussed almost entirely on orbit determination until around 1950 when two cometary models were put forward. Oort's hypothesis of a cloud of comets surrounding the Solar System (*Bull. Astr. Insts. Neth.,* **11,** 91, 1948) and the dirty iceball theory of Whipple (*Astrophys., J.,* **111,** 375, 1950) provided a new impetus to work in the field. Shin Yabushita of Kyoto University, writing in the *Quarterly Journal of the Royal Astronomical Society* (**24,** 430-442, 1983), examines the dynamical evolution of comets and its implications for cometary origin.

The extremely elongated orbits of comets mean that planetary pertubations have to be combined with stellar perturbations. There are probably a very large number of comets so that, rather than looking at details of an individual cometary orbit, statistical considerations are needed.

Once a comet has been observed and its oscillating orbit determined, it is possible to extend the orbit both forwards and backwards in time. With the average orbital period being a few million years and three or four new comets discovered each year there must be at least 10^7 comets presently associated with the Solar System. Note that these are only those comets whose perihelia lie within the observable region for the Solar System - perhaps within 4 AU from the Sun.

It is pointed out that the Oort cloud was postulated to contain some 10^{11} comets. When examining the effects of planetary perturbations, there are four problems to consider. Loss of comets from the Solar System, evolution from nearly parabolic to short-period orbits, evolution of the distribution of binding energy (the reciprocal of the semi-major axis) among comets and the effects of perturbations by passing stars and by giant molecular clouds are the four major topics.

Planetary perturbations are responsible for the orbits of some comets becoming hyperbolic with consequent loss from the Solar System. More than 90% of comets are expelled in 6 million years.

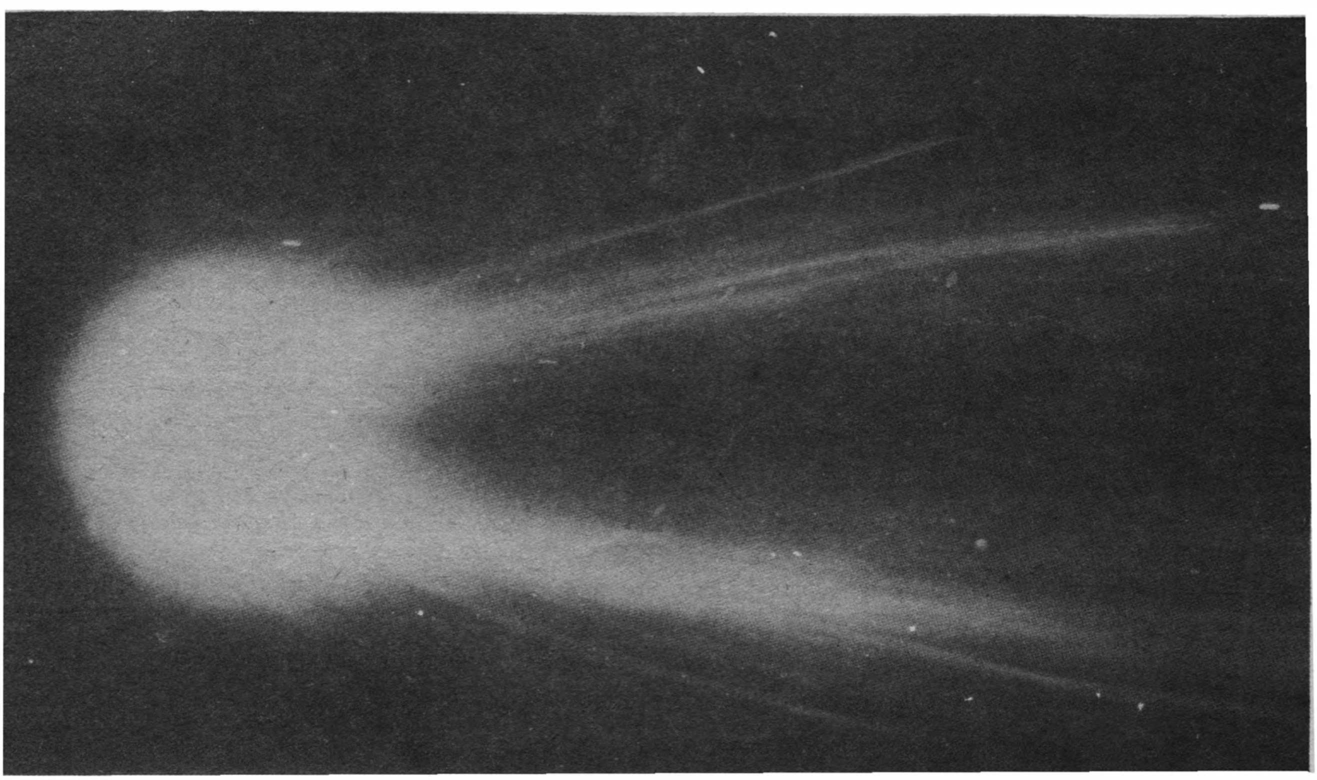
Unfortunately, our observations cover only a few hundred years so we do not know if the population is in a steady state, though the number of new comets seems too large to be consistent with the steady-state hypothesis - three out of four comets are not re-observed after their first perihelion passage.

Consideration of the many comets with semi-major axis greater than 2×10^4 AU and perihelion distance less than 4 AU leads to aphelion distances greater than 4×10^4 AU, at which distance perturbations by passing stars will be important. Oort's cloud of 10^{11} comets may be at 5×10^4 AU (about 1 light year) and would be strongly affected by encounters with giant molecular clouds of masses between 10^4 and 10^5 solar masses.

The distribution of cometary perihelion points in the celestial sphere is concentrated in the northern sky.

Even though there is no satisfactory theory for the

The appearance of Halley's comet in 1910. *Hale Observatories*



formation of comets, it is probable that they originated in the primitive solar nebula. They may have formed in the vicinity of Neptune and have been gradually repelled to the distance of the Oort cloud, but at distances beyond Neptune it seems to take too long for condensation of comets and the formation of cometary nucleii is doubtful.

Some researchers believe that intra-Solar System comets are necessary for the initial evolution of terrestrial life. The primitive Earth either had an oxydizing atmosphere or no atmosphere at all, but for organic compounds to be formed the atmosphere must be reducing. Apparently organic compounds need to be brought from somewhere outside the Earth and estimates of the need for around 100 cometary impacts have been made.

Extra-solar origin of comets by capture has also been discussed but the mechanism is uncertain. The intra- or extra-Solar System origin question may be resolved if the Giotto exploration of Halley's comet reveals differences between the isotope ratio of cometary carbon and that of Solar System material.

EARTH/COMET COLLISIONS

It has been proposed that the cause of the Cretaceous-Tertiary extinction event was due to an impact and consequent injection into the Earth's atmosphere of a large amount of extraterrestrial material. This would have led to a temporary cessation of photosynthesis (similar to the nuclear winter) and collapse of most food chains due to blockage of sunlight, a large temperature variation on a short time scale and a dramatic change in atmospheric chemistry leading to the formation of enormous quantities of toxic acids. Several similar mass extinctions are thought to have taken place and Z. Sekanina and D.K. Yeomans have investigated the frequency of encounters and collisions between the Earth and comets. They find collision rates compatible with those required for the major geolocial extinction events. The investigators both work at the Jet Propulsion Laboratory and report their work in "Close encounters and collisions of comets with the Earth," *Astronomical Journal* **89**, 154-162, 1984.

They used a computer to scan a catalogue of comet-orbits to find all instances when a comet's minimum geocentric distance was less than 2500 Earth radii. The short-period comets are strongly represented and the predicted collision rate gives a collision with an active comet every 33 to 64 million years.

They note that such collisions are considerably less frequent than collisions with asteroids. (Earth-crossing asteroids with absolute magnitude brighter than 18 are estimated to collide with the Earth once every 300,000 years)..

HUBBLE SPACE TELESCOPE

In 1986 NASA plans to launch the Hubble Space Telescope. It will be the first large aperture, long-term optical and ultraviolet observatory in space. In 1982 a special session of Commission 44 of the International Astronomical Union met in Patras, Greece, to hear details of the telescope, its capabilities and planned observations. This session was organised jointly by the European Space Agency and NASA and its deliberations are reported in NASA CP-2244.

In some respects the operation of the telescope will represent the first qualitative improvements in telescope capabilities in the optical domain since the completion in 1948 of the 200 inch Hale Telescope at Palomar Mountain. Its orbit outside the Earth's atmosphere will allow an angular resolution, a sensitivity and a wavelength coverage unachievable from the ground. Since it will be inserted into orbit and maintained or updated by the Shuttle, it is expected to remain operational for over 20 years.

Observations will be at the cutting edge of much of the astronomical research of the next decade. It will consist primarily of a 2.4 m mirror, together with appropriate instrumentation to cover wavelengths from the far ultraviolet to the far infrared.

Its operation is under the guidance of the Space Telescope Science Institute, operated by the Association of universities for Research in Astronomy, Inc. located on the campus of the Johns Hopkins University in Baltimore, Maryland.

Using the telescope, we will be able to see more details in close objects and more distant objects at a wider selection of wavelengths than is possible from the ground. "After a period of hiatus in which astronomers seemed most involved in the digestion of the results flowing from the capital investment of the previous generation, it may well be that the next two decades will be remembered as the heroic construction phase for observational astronomy."

The image surface is divided into eight segments, each supporting a specific scientific instrument or fine guidance sensor. The central region is devoted to the wide field/planetary camera which could be used for cosmological research, increasing our ability to see objects at a distance 10 times that of the 200 inch telescope. Cepheid variables should be detected in the Virgo clusters of galaxies, diameters of HII regions out to the Coma clusters as well as globular clusters and galaxies of very large red-shift. We will be able to probe into early epochs and remote parts of the observable universe and examine details of galaxies presently hidden from us. Optical counterparts of extremely distant quasars and radio galaxies should be observable.

Globular clusters in our Galaxy will be probed and examined in detail, as will the Galactic Centre.

With few planetary missions available in the foreseeable future, the Hubble Telescope will be our primary source of information on the planets. Resolution of details on Jupiter will be comparable with that available from Voyager flyby images. We will be able to obtain better observations of Pluto and its satellite. Planets moving round other stars may be detected from their gravitational effects on the positions of the stars.

Even surface details of asteroids may be observable. Supernovae should be detectable up to a redshift of about 0.3. Comet Halley will be observed. Positions of stars will be available to within a accuracy of 0.002 arcseconds, so double stars will be detectable in some spectroscopic binaries. The accuracy of measurement corresponds to about 10 km at the distance of Saturn.

The report ends with a paper by M.S. Longair of the Royal Observatory, Edinburgh in which he reflects on the impact the use of the telescope will have on astronomy. He lists "what we need to know about astronomy and cosmology" and ends with the hope that the ultimate scientific return will be as great as that emanating from the observatory of Tycho Brahe, whose work formed the basis for the laws of Kepler and the Law of Gravity of Newton.

"If we achieve with Space Telescope anything which even remotely approaches the fundamental importance of that great discovery, Space Telescope will have achieved real greatness."

ASTRONAUTICS AT LAUSANNE

The 35th Congress of the International Astronautical Federation was held in Lausanne, Switzerland on 7-13 October 1984. Len Carter, the Society's Executive Secretary, reports on the proceedings below. Further reports on the Technical Sessions will be included in later issues.

Introduction

The 35th IAF Congress held in Lausanne, in the French speaking part of Switzerland on the borders of Lake Geneva, attracted an audience of about 750. Negotiating the trip between Geneva Airport and Lausanne, and thence to the appropriate hotels at the other end of town, together with daily bus rides to and from the Congress venue itself, all proved surprisingly easy.

Congress activities were centred in the Palais de Beaulieu, a venue big enough to handle an army without overcrowding and with rooms, halls and facilities extending in so many directions that one needed to develop an acute sense of navigation at an early stage.

The Congress was held under the auspices of the Swiss Association for Space Technology, a relative newcomer to the astronautical scene and which thus explains why most of the arrangements, including an interesting exhibition, were in the hands of professional organisers - who presented a slick but impersonal touch.

Participants were able to take their pick of 61 sessions, containing nearly 500 technical papers presented by scientists and engineers from more than 30 countries. Eight technical sessions, held concurrently on most days, attracted an average attendance of 40 and demanded early development of Will-o'-the-wisp characteristics. There were also a number of social events, nearly all of which were on a fee-paying basis.

Opening Session

The first hour of the Opening Ceremony was taken up by the presentation of a host of formal messages, following the usual pattern, all read out in detail though most had already been printed in full in the official programme.

Attending the conference. From left, Jim Harford (AIAA), Dr. Les Shepherd, John McLucas and Len Carter.

The Invited Lecture was by Mr. R. Sunaryo from Indonesia, a representative of a developing country who tackled the theme of "Space to Benefit All Nations." This was taken up later in a Forum discussion, though this was not in the form of a free-for-all but rather a structured programme of four talks.

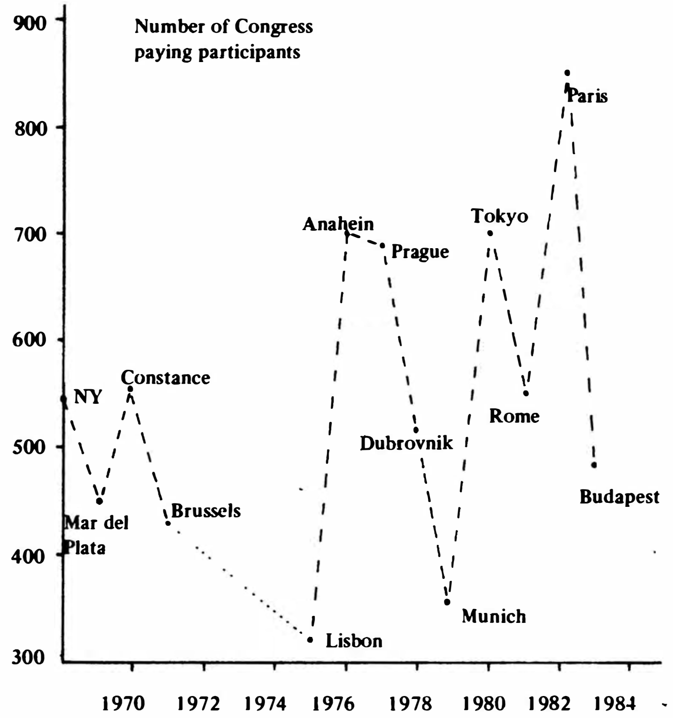
Exhibits

The immediate front entrance of the Palais was occupied by the registration and information areas, bank, postage and souvenir stalls. Behind was a very fine display of exhibits which occupied most of the hall. Brilliantly lit, attractively designed, nicely spaced out and representative of a wide range of space activities, the Shuttle and Ariane were prominent. Displays included both models and charts, as well as plenty of literature. On display were rocket motors from SEP, a 1/20th-scale Ariane 4 from Aerospatiale, a full-scale model of Giotto on the ESA stand, Spacelab was shown by MBB and the Shuttle featured prominently on the NASA stand. Dornier was one of two manufacturers displaying satellite receiving stations, the appropriate antennae being housed outside. Both were receiving pictures of Meteosat 2 and attracted considerable interest. The pictures had first been transmitted from the satellite to ESOC at Darmstadt, where they had been processed i.e. with markers and lines to indicate land masses imposed, the result then being beamed up to Meteosat 2 once more for retransmission to ground receiving stations. On return the pictures were printed out. A set of nine provided full coverage of the Earth though actually they came in three different sets, namely those depicting cloud cover, those picking up infrared and those giving a straightforward optical view. One could thus get a continuous bird's eye view of the weather over the UK throughout the Congress.

Business Sessions

The first session of the IAF General Assembly on Monday, 8 October began with a warning shot from the President indicating that he considered that the dues of the Member-Societies would have to be increased by 15% to meet the growing needs of the Federation. This was despite the fact that the accounts showed a reserve of SFr 80,000 at the present time. He considered this to be preferable to the alternative of increasing the IAF share of the Congress Registration Fee which, at Lausanne, was SFr180 out of a total fee of SFr400. The Swedish host society for the next Congress, at Stockholm, would indicate later that the Registration Fee would be raised to SFr460, but this would not involve any increase in the IAF component. This matter was returned to later in the Agenda at the second session of the Assembly.

The Agenda having been approved, the meeting turned



The number of paying participants at the IAF Congresses from 1968 to 1983 (1972-74 figures not included).

to the subject of Membership. One new application for Institutional, non-voting, membership from a Swiss company was accepted and the membership of an Italian organisation terminated, leaving the total membership, in all catagories, unaltered at 63.

The International Programme Committee for the 36th Congress, at Stockholm in 1985, was approved by the Assembly, with Dr. J.P. Layton (USA) and Dr. Y. Rycsantsev (USSR) as its Co-chairmen. The other members would be Dr. Boeff of Sweden, the Chairmen of all the IAF Committees and the appointed representatives of the IAA and IISL. This Programme Committee structure was a new one that would be followed in future Congresses.

The main activities of the IAF are now concentrated in the hands of ten scientific and technical committees as well as the important Membership and Education

The BIS delegation receives the news of the proposed 15% increase in fees.

Committees and the IAA and IISL committees. The Assembly was required to approve new general and specific Term of Reference for these, which it duly did. One of the principal duties of the committees is the organisation of the symposia and lecture sessions at the annual Congresses and it is on this account that the membership of the Programme Committee is now mainly based upon the committee chairmen.

As regards the plans for the technical sessions at the 1985 Congress, Dr. Layton indicated that his committee proposed to reduce the number of technical sessions from 61 to 54 and also aim for a lower number of papers per session.

Introducing the proposals for the 36th International Astronautical Congress in 1985, the Swedish delegate stated that this would take place in Stockholm from 6th to 13th October. The Registration Fee would be SFr460 for full participation with the IAF share remaining at SFr180, as already indicated. Students would pay SFr50 and the charge for Accompanying Persons would be SFr200. The Swedish representative gave a short illustrated talk about the Congress Venue and interesting aspects of Sweden's capital city.

It was announced that the theme of the Congress would be "Peaceful Space and the Problems of Mankind."

The provisional plans for future Congresses were put before the Assembly for information, it being noted that action on the 1986 Congress was not possible because no firm commitment had been made by any of the member-societies to play host in that year. It should be noted that it is the accepted practice in the IAF to hold its Congress in any given country at the invitation of the Voting Member Society of that country. A tentative offer had come from Indonesia but had not been backed up, so far, by any definite commitment. It was left to the Bureau to try to resolve the problem and to secure a definite offer before the General Assembly in 1985.

The situation beyond 1986 was as follows: the BIS had notified the Bureau that it was now giving firm throught to having the Congress in the UK in 1987 and hoped to be in a position to offer a firm invitation to the IAF at the next meeting of the General Assembly at Stockholm. Other offers were on the table from East Germany, India and Israel, so the possible line-up might be:

1986: Indonesia?
1987: UK
1988: East Germany
1989: India or Israel

Reports on relations with other international organisations continued to figure prominently in the deliberations of the General Assembly, though there had been a conscious attempt to streamline the presentations. The importance of these items is indicated by the growing extent to which the Federation is being drawn into the affairs of official bodies concerned with World collaboration in space. As an example, reference may be made to the IAF report which has been prepared for the UN on the international implications of Large Space Structures. The IAF was involved, increasingly, in jointly organised meetings with COSPAR and other international bodies with which it had formed firm bonds.

The President of the International Academy of Astronautics, Dr. George Mueller, reporting briefly to the Assembly, stated that membership now numbered 558, made up of 11 Honorary Members, 210 Members and 337 Corresponding Members. It was planned to increase the total by 220, all at the full membership level. The Academy was founded in September 1959 but will cele-

brate its Silver Jubillee at Stockholm in 1985. This is appropriate insofar as the inaugural meeting of the Academy was held during the 1960 Congress, also at Stockholm.

Dr. Diederiks-Verschoor, President of the International Institute of Space Law, reported on a joint meeting with the UN Committee on the Peaceful Uses of Outer Space which had been held in March. The topics had included a discussion on Nuclear Power Sources in Space. When the General Assembly returned to financial matters during its second session, the President's proposal to increase IAF-membership subscriptions by 15% had been moderated, following a further meeting of the Finance Committee, to a slightly more acceptable figure of 10%. In announcing this, Dr. Buedeler, Chairman of the Committee, recommended the acceptance of the Budget for 1983/84 and of the Estimates for 1984/85. He noted the concern of the Finance Committee not only over the dues increase but also in the escalation in the Congress Registration Fee. The need for seeking alternative sources of income thus remained a matter of great importance.

The General Assembly, somewhat grudgingly, endorsed both the proposal to increase the Membership-Fee (18 in favour; 2 against; 8 abstentions) and to accept the Registration Fees proposed for Stockholm (19 in favour; 0 against; 9 abstentions).

The final item of business at meetings of the IAF General Assembly at any Congress is the election of Officers for the ensuring year. The Nominations Committee, consisting this year of the representatives of Spain, Yugoslavia, Austria, Japan and Poland, recommended the election of the following:

President:
Dr. Jerry Grey (USA)

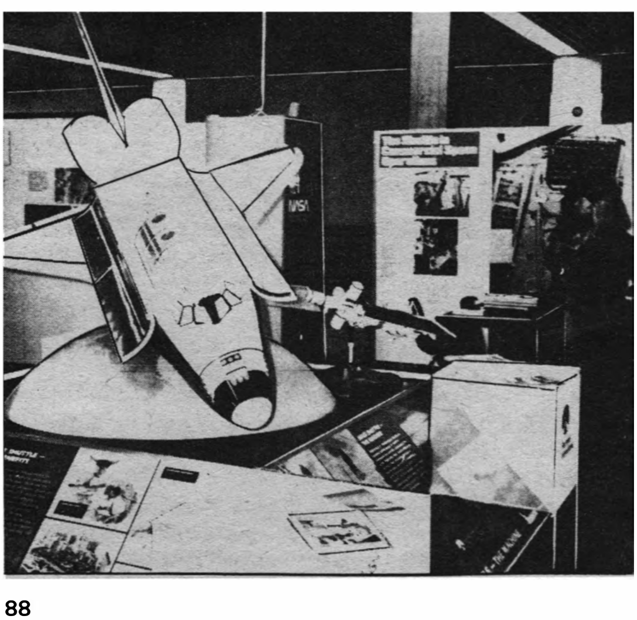
Vice Presidents:
Dr. R. Sunaryo (Indonesia) 2nd Term
Dr. Yang Gia Chi (China) 2nd Term
Dr. G.G. Chernyi (USSR)
Dr. Van Reet (Belgium)
Dr. Joachim (German Democratic Republic)

The General Assembly approved the recommendations of the Nominations Committee and the list was adopted *in toto.*

BIS Participation in the Organisations of IAF Affairs

As a founder member, the BIS played a dominant role in the business of the IAF throughout the 1950's. In the subsequent decade the Society's involvement in the Federation was reduced as other bodies joined and sought participating roles. Through most of the 1970's it was at a relatively low level but this trend is now reversing with members of the BIS beginning to undertake an expanding role in the work of the Federation, a situation which, hopefully, will reach a climax in 1987.

The Shuttle display.



Roy Gibson inspects the photographic display

At Lausanne the official representation of the Society in the General Assembly was again delegated to the Executive Secretary, L.J. Carter, and to our International Liason Chairman, Dr. L.R. Shepherd, whose combined experience of IAF affairs extends back to the organisation's birth. Both representatives take a fair share in the work of the Committees; L.J. Carter in the Education Committee and Dr. L.R. Shepherd as current Chairman of the Space Energy Power & Propulsion Committee (and, consequently, a member of the 1985 Programme Committee) as well as the Finance Committee. The BIS Council was also represented at the Congress by its retiring Vice-President, Dr. A.R. Martin. Several other notable members of the Society were present, some of them wearing other hats. One "old timer" deserving mention, was Eric Burgess, now of California. Such is the far-flung nature of our membership that a significant number of those present at the Congress who are qualified to wear the blue tie with its stars and rocket device, spoke with accents decidedly non-British, those with an American flavour being particularly prominent. It should also be mentioned that another Briton,who served as IAF President in 1979 and 1980, Roy Gibson, also continues to play an active role in IAF affairs.

The BIS participation extends to the Academy of Astronautics. Professor G.V. Groves served for some time on the Board of Trustees of the Academy in Section 1 and, currently, Dr. L.R. Shepherd is a member of the Board in Section 2 and is also Chairman of the newly-formed Interstellar Space Exploration Committee. Notable members of the BIS's now famous Interstellar "fellowship," Tony Martin and Alan Bond, attended the inaugural meeting of this Committee and, as Chairman of it, Dr. L.R. Shepherd also serves on the Academy's Scientific Programmes Committee. He is also a lesser member of the IAA Committee on the History of Astronautics, which has a very strong BIS presence - mostly American. Co-

The BIS delegation at work.

Chairman of the History Committee is F.C. Durant III, with Dr. John Becklake (a former Council Member) as a particularly active member of the Committee, as are non-natives Mitch Sharpe (Editor of the *JBIS* 'Astronautics History' issues) and Fred Ordway.

Our President, A.T. Lawton, serves on the CETI Committee. He was not at Lausanne but is now happily recovering from the serious indisposition that prevented him from attending. Nor it would not be forgotten that both the current and Past Presidents of the Academy of Astronautics are Honorary Fellows of the BIS.

The view of the Society's Council is that the IAF is a very important body in the field of international collaboration in space and they regard it as particularly important that it should receive the maximum support from all of its member societies.

Press

Press facilities were somewhat limited. As far as could be seen, the press had to make do with one small room so it is difficult to describe them as being fêted this time round. Press accreditation, when it *was* effected, brought no access to preprints, press handouts or material of any sort. There was no list of participants nor a Congress newspaper.

Education

One of those enjoying new Terms of Reference was the Education Committee, henceforth to be concerned with the effects of space on both the formal and informal education processes, and *vice versa*. Its brief includes specific student activities and supervised youth research experiments besides the use of satellites, spacecraft and ground-based facilities for educational purposes.

The committee's principal activity will, of course, continue to be in assembling the best possible programme for each IAF Congress with two sessions allocated for the Stockholm Congress on:

1. Space Education: uses, motivation and benefits, and
2. Space Systems and Education.

A departure from the norm appeared in the shape of a proposal for a "Young Astronaut Programme." This originated in an announcement by President Reagan designed to utilise space development to stimulate the greater study of science and technology in the US. The concept is designed to reach some 5,000 US elementary schools and be supported by an expanding NASA educational programme.

The value of such a move is self-evident. Not only would it encourage a greater pursuit of science and technology but, eventually, will create a much more technologically proficient workforce which will place the US in a commanding position in the high technology world of the future.

To what extent a similar plan will be adopted by other countries remains to be seen but, undoubtedly, it is a most excellent conception. There is no doubt that a similar project would prove of great interest to the young in the UK, as well as being applicable to other countries which support ESA. There is a greatly-expanded role for our own Society here in fostering such concepts.

The Education sessions included an interesting contribution by Dr. Bettye Burkhalter on experimentation for the Getaway Special canisters. Besides listing many valuable ideas that had surfaced in making use of these relatively small Shuttle-carried canisters, the author addressed herself to the more basic problems of how to reach those teachers and parents who ought to be involved. This, she admitted, is easier said than done and, with the US now in the midst of a major upheaval aimed at academic excellence, this aspect has slipped somewhat.

A suggested programme to put things right had three stages:

1. Educational Leadership.
2. Wide public support.
3. The involvement of classroom teachers - this being the crucial area where things actually happen.

The ingredients required were:

1. Sponsorship, presumably both government and industrial.
2. A programme for the guidance of teachers which produced the material for them to use, though it was not specified whether this was to be set out under traditional classroom subjects or apply to some of the major topics associated with space, *viz:*
   i. Computers/Robotics
   ii. Biological studies.
   iii. Technical (engineering/electronic) etc.

It looked as though point 2(i) had to be resolved first. An Apple for the teacher is long overdue. Students, nowadays, sometimes leave their teachers far behind.

An interesting contribution from the floor came from Buzz Aldrin, the Apollo 11 astronaut. He explained that he had been concerned about the generation gap since 1970, not the one due to parenthood but one that concerned the degree of curiosity in those who will inherit a different world. This stemmed very much from divergent backgrounds while growing up. The older generation had experienced a world of limitations and had been much concerned about what we could and could not do. Now, a new challenge is before us and we must explore how we can tap the resource of the new generations interested in space. If they look they will find immense possibilities but they must have confidence.

Reports on the Technical Sessions will be included in subsequent issues of Spaceflight. *The first are included overleaf.*

LOW EARTH ORBIT AND RETURN

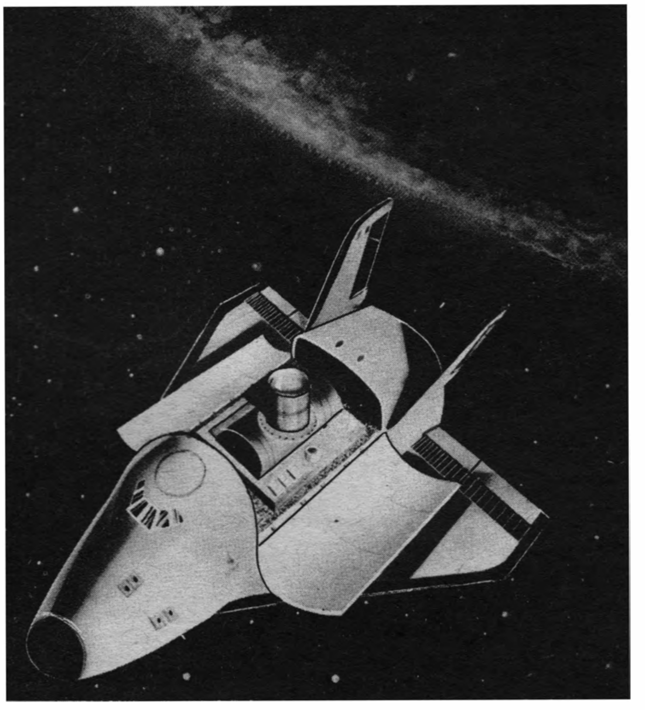
The session provided a summary of recent developments in space transportation. Three papers were given that presented analysis and design definition to date for a new generation of expendable launch vehicles to replace the Japanese H1 and European Ariane 4. The H2 will place two tonnes in geostationary orbit and will have Lox/LH_2 first and second stages along with solid rocket boosters ignited at liftoff. The Ariane 5 will place three-four tonne satellites in geosynchronous orbit; its lower stage consists of two large solid propellant motors. The second stage is Lox/LH_2, while the third can be either storable of cryogenic. These launchers are planned for the 1990's.

The latest engineering definition for the 'Hermes' manned vehicle was described. The vehicle would be launched on Ariane 5 carrying four men and would be capable of landing at either the Guiana launch base or at other European sites. It would be used in conjunction with space stations in the late 1990's. An unmanned reusable re-entry vehicle was described in a separate paper. It could be launched by Ariane 4. Its prime purpose would be to carry materials for space manufacturing back and forth to a space platform; the preferred configuration would carry a payload mass of 650 kg and have the general shape of the Apollo command module.

A survey of the evolution of the Soviets space transportation system was presented. This included the Soyuz and Soyuz-T spacecraft for manned space transport and the Progress spacecraft for unmanned transportation. Both systems are used to support the Salyut station; further developments include the Cosmos 1443 system. To date (October 1984), 35 manned and 23 cargo spacecraft have been launched to support Salyut. The reliability of these systems using flight-proven subsystems was stressed, along with their expected continued use for a number of years.

The three final papers covered the successful testing of the Japanese H1 vehicle Lox/LH_2 propellant system, cost effectiveness of an air-launched rocket system and performance enhancement considerations for the US Space Shuttle using an aerospike concept.

C.A. ORDAHL



The French 'Hermes' small shuttle concept is a possibility for the Ariane 5 project. *CNES*

CETI-SETI

Two CETI-SETI sessions were held at the Congress, with excellent papers presented in both. C. Ponnamperuma discussed chemical evolution and the results of the search for organic molecules in space of abiotic origin. The presence of organic molecules in the atmospheres of stars and in interstellar space might be evidence that chemical evolution is commonplace in the Universe and cosmic in nature.

J. Oro described main requirements (pre-solar, solar and planetary) for the existence and evolution of life. The appropriate conditions were satisfied in the Solar System on Earth and Saturn's satellite Europa and, more ephemerally, on Mars and Venus.

M.D. Papagiannis summarised the most significant results from the first Symposium of the International Astronomical Union on the search for life in the Universe (June 1984, Boston, Mass, USA).

N. Balàza presented the results of his calculations of the habitable zones in our Galaxy and some suggestions concerning new strategies connected with this approach. A.R. Martin and A. Bond reviewed the many aspects of the Fermi Paradox concerning the existence of intelligent life ("If there are so many people out there, where are they?"). This analysis led them to the conclusion that we are alone in the whole Galaxy! B.R. Finney believed that SETI will become part of an overall expansionary process and crucial to the reconnaissance of the Galaxy for possible colonisation sites. Astronaut U. Merbold, A. Souchier and A. Ducrocq presented results of the SETI-modelling experiment on Spacelab 1.

F. Valdes and R.A. Freitas presented a paper on the search for extraterrestrial artifacts (SETA). They also reported on the unsuccessful search for the tritium hyperfine line at 1,516 MHz in 108 astronomical objects. This line is ideal for SETI work because the isotope is rare and the frequency corresponds to the well known 'water hole.'

D.K. Cullers presented a paper with B.M. Oliver and J.H. Wolfe on the detection of narrowband pulsed signals by a rotating beacon with a directional antenna. J. Tarter reported on the use of the very large array (VLA) synthesis radio telescopes to perform parasitic SETI when looking for radio stars. M. Subotowicz discussed the threats to CETI-SETI (and to the existence of life up to the level of homo sapiens), analysing the problem first from the standpoint of the cosmological principle.

M. SUBOTOWICZ

SPACE STATIONS AND PLATFORMS

Comprehensive discussion on the state-of-the-art and plans for technologies relevant to the Space Station and Platform were made by US, European and Japanese speakers. Highlights included:

1. Strong indications of a need for larger than previously stated electrical power supplies for the Space Station (over 175 kW).
2. De-emphasis on gallium arsenide solar cell work by the US (insofar as Space Station application is concerned).
3. Elevation of solar dynamic power supply as a serious contendor *vis a vis* photo voltaic for the Space Station.
4. Supercritical water oxidation of waste products under evaluation.
5. Broad consideration being given to utilisation of solar radiation in orbit (plant growth, illumination, recreation, health, as well as electrical power) through collection, filtering and distribution by optical fibre network.
6. Quantitative evaluation of human productivity in space. Assembly and construction under simulated orbital conditions show relatively favourable results of human productivity in EVA tasks - as compared with that expected from pre-Shuttle experience.

JOHN DISHER

SATELLITE DIGEST-180

Robert D. Christy

Continued from the January issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

STS-41D 1984-93A, 15234

Launched: 1242*, 30 Aug 1984 from the Kennedy Space Center.
Spacecraft data: Delta-winged vehicle, 37 m long and 24 m across and with mass around 70 tonnes (excluding payload).
Mission: First flight of the orbiter *Discovery* after a delay caused by a fuel leak during a June launch attempt. The crew consisted of Henry Hartsfield, Michael Coats, Steven Hawley, Richard Mullane, Judith Resnik and Charles Walker. Major events were launchings of three communications satellites, testing of a 31 m long, 4 m across solar array, and drug processing. *Discovery* landed at Edwards Air Force Base on Sept 5.
Orbit: 297 x 314 km, 90.43 min, 28.47°.

SBS 4 1984-938, 15235

Launched: 2040*, 30 Aug 1984 from the payload bay of *Discovery*.
Spacecraft data: Standard Huges HS-376 vehicle, cylindrical, with length 2.82 m (6.7 m on extension of the solar array) and diameter 2.16 m. The mass in geosynchronous orbit is 1117 kg, reducing to 571 kg on depletion of fuel.
Mission: Commercial comunications satellite.
Orbit: Geosynchronous above 101° W longitude.

SYNCOM IV-2 1984-93C, 15236

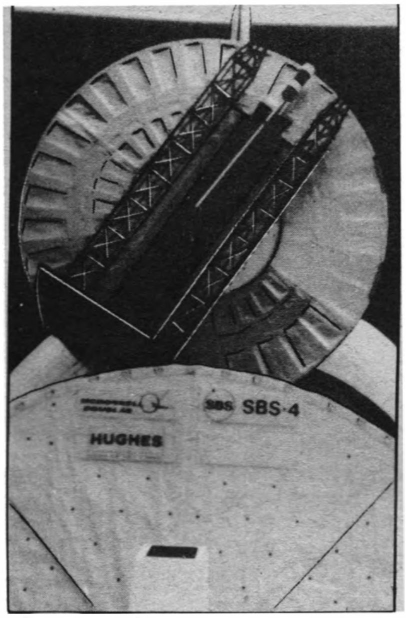
Launched: 1313*, 31 Aug 1984 fro the payload bay of *Discovery*.
Spacecraft data: Cylinder about 3 m long and 4.2 m diameter.
Mission: US Navy communications.
Orbit: Geosynchronous above 105° W longitude.

TELSTAR 3C 1984-93D, 15237

Launched: 1320*, 1 Sep 1984 from the payload bay of *Discovery*.
Spacecraft data: Similar to SBS 4 except dimensions are 2.77 m, 6.83 m and 2.16 m, and the masses 1225 kg and 653 kg, respectively.
Mission: Communications satellite.
Orbit: Geosynchronous above 125° W longitude.

COSMOS 1592 1984-94A, 15257

Launched: 1020, 4 Sep 1984 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and a cylindrical, supplementary payload at the forward end. Length 6 m, max diameter 2 m and mass around 6000 kg.
Mission: Military photo-reconnaissance,



The Syncom satellite rotates out of Discovery's cargo bay in the Shuttle mission last August.

recovered after 14 days.
Orbit: 225 x 287 km, 89.67 min, 72.88°.

COSMOS 1593-1595 1984-95A-C, 15259-61

Launched: 1550, 4 Sep 1984 from Tyuratam by D-1-E.
Spacecraft data: Possibly each satellite is a cylinder with domed ends, covered in a drum-shaped solar array with length and diameter both about 2 m, the mass may be around 700 kg.
Mission: Triple launch of satellites in the GLONASS navigation system.
Orbit: 19090 x 19170 km, 675.73 min, 64.79°.

COSMOS 1596 1984-96A, 15267

Launched: 1913, 7 Sep 1984 from Plesetsk by A-2-e.
Spacecraft data: Possibly similar to the Molniya satellites, having a cylindrical body with a conical motor section at one end with power being provided by a 'windmill' of six panels. Length about 4 m, diameter 1.6 m and mass around 2000 kg.
Mission: Missile early warning satellite.
Orbit: Initially 604 x 39248 km, 707.61 min, 62.95° then raised to 718 min period to ensure daily ground track repeats.

NAVSTAR 10 1984-97A, 15271

Launched: 2150, 8 Sep 1984 from Vandenberg AFB by Atlas.
Spacecraft data: Box-shaped body, approx 2 m on each side with two solar panels, mass around 800 kg.
Mission: Navigation satellite.
Orbit: 19956 x 20409 km, 718.01 min, 63.26°.

CHINA 16 1984-98A, 15279

Launched: 0545, 12 Sep 1984 from Shuang Cheng Tse by FB-1.
Spacecraft data: Not available.
Mission: Possibly remote sensing or photo-reconnaissance, a capsule was probably recovered on Sep 17.
Orbit: 174 x 400 km, 90.27 min, 67.94°.

COSMOS 1597 1984-99A, 15287

Launched: 1025, 12 Sep 1984 from Plesetsk by A-2.
Spacecraft data: Similar to Cosmos 1592.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package. Recovered after 13 days.
Orbit: 211 x 244 km, 89.12 min, 82.34°.

COSMOS 1598 1984-100A, 15292

Launched: 1554, 13 Sep 1984 from Plesetsk by C-1.
Spacecraft data: Similar to Cosmos 1593.
Mission: Navigation satellite.
Orbit: 970 x 1016 km, 105.02 min, 82.94°.

GALAXY 3 1984-101A, 15308

Launched: 2220, 21 Sep 1984 from Cape Canaveral by Delta.
Spacecraft data: Similar to SBS 4 except masses are 1218 kg and 520 kg.
Mission: Commercial communications satellite.
Orbit: Geosynchronous above 93.5° W longitude.

COSMOS 1599 1984-102A, 15318

Launched: 1430, 5 Sep 1984 freom Plesetsk by A-2.
Spacecraft data: Possibly similar to Cosmos 1592.
Mission: Long life, military photo-reconnaissance.
Orbit: 180 x 327 km, 89.58 min, 67.14°.

COSMOS 1600 1984-103A, 15324

Launched: 0810, 27 Sep 1984 from Tyuratam by A-2.
Spacecraft data: Similar to Cosmos 1592.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 349 x 416 km, 92.22 min, 68.98°.

FROM THE SECRETARY'S DESK

Eurospace and ESA

I was very pleased to see the developing Eurospace-ESA accord, exemplified by a recent *Spaceflight* Editorial, for our Society has always been very close to both organisations.

The origin of Eurospace really stems from the activities of the late Michael Golovine, BIS President at the end of the 1950's and an incredibly active internationalist. He got in touch with M. Cristofini of SEREB to suggest a joint study designed to open up fruitful international space ventures e.g. communications satellites, reconnaissance satellites and many supporting technical studies.

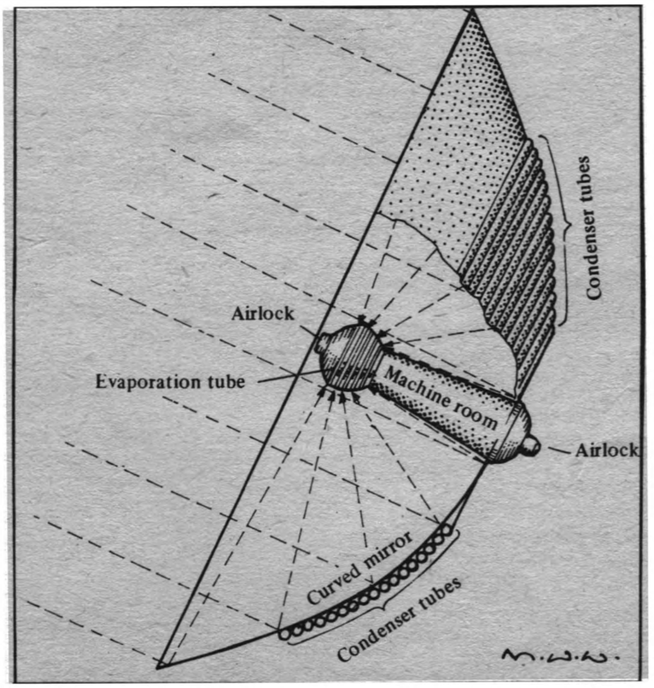
The study attracted little notice at the time but collaboration between Hawker Siddley Aviation (later British Aerospace) and SEREB (later Sud-Aviation) fuelled the interest of other companies. In no time at all the group had grown to 18 Anglo-French companies and, before long, many other companies from all over Europe became involved, thus leading to the creation of EUROSPACE.

Space Station Update

We have, at last, secured a copy of the famous book by Hermann Noordung published in 1929 called *Das Problem Der Befahrung Des Weltraums: Der Raketen-Motor*.

This was a book to which the pre-war BIS Technical Committee frequently referred, though none had actually seen it, for the simple reason that no copies were available. The most they had to go on were *reports* of what the book contained! To a large extent, doubtless, the later BIS space station designs were influenced by the ideas of Noordung (actually this was a pseudonym for an Austrian named Potocnic) even though they were at least one stage removed and without sight of his actual drawings.

Now, after decades, we have secured a copy and are pleased, for the record, to reproduce one of the space station drawings taken from it.



Souvenir Plates

Not many space souvenirs have emanated from the UK so far, so it is all the more delightful to record that Royal Doulton commemorated the Space Shuttle *Discovery* launch on 25 June with the production of bone china plates. In fact, the Shuttle actually carried three of these. All are now on permanent exhibition, one being aboard the ship *RRS Discovery* - now berthed at St. Catherine's Dock, London, as part of the collection of historic ships - so providing an historic link with another mission of 83 years ago when Captain Scott led his expedition to the Antarctic. This *Discovery* had also used fine china made by the same company so it was all the more apt for the Shuttle plates to include the emblem of Captain Scott's expedition - used to decorate the original china - as well as the flight patch of the Shuttle itself.

(A 5-inch reproduction of the plate is now available from many shops at £7.95).

Gourmet's Delight

Generous compliments have often been made about Society events involving meals, Banquets and Dinners. How do we do it?

It began long ago when the Council arranged the first function of this type. I was totally inexperienced and without the slightest notion where to begin. As time pressed, I sought guidance from the Council and received in return 12 totally different concepts - all completely at variance with each other.

In desperation I chose a menu and wines to give me the finest feed-up for years and then waited for roars of complaint. None came, so I have done the same thing ever since.

Sometimes, apparently insurmountable obstacles appear. Once such took place at the IAF Congress in Barcelona where the BIS had to provide a Dinner at the Ritz to selected guests. The menu was unintelligible and the dishes unknown. The impasse was resolved simply

by asking the Manager to produce a meal to my own satisfaction.

It was the same at the IAF Congress in Stockholm, where the local phraseology was even more outlandish. One variation which took place then was that we dispensed with formal speeches. *Everyone* present (there were about 30 of them) spoke as and when the Spirit moved him, rather in the manner of the early Congregational Churches. The requirement was simply "to ding one's glass" make a few suitable remarks and depart gracefully.

I remained to the end, solely from a sense of duty.

Going like Hot Cakes

Members of the Society interested in extending their Library collections should secure a copy of the Society's List of Surplus Books for sale. Those who have availed themselves of this so far (the lists are updated every month or so) appear to be well-satisfied, judging by the number of books sold.

Our latest list features many technical, US Government and other Reports, not normally easily available so the opportunity to obtain them should not be missed.

Would-be purchasers are emerging from as far afield as Australia, New Zealand and America.

At this rate, I doubt if we shall find enough books to satisfy everyone.

Space Coins and Medallions

Recent correspondence in *Spaceflight* about coins and medallions on astronomical and space subjects has made me seek more information on this very interesting topic. To what extent older coins and medallions are still around has yet to be seen but a catalogue of the Library of the American Numismatic Society, for example, proves that they have appeared in a steady stream from Greek and Roman times.

Few members will have the opportunity of digging back in time to secure some of the older items and, if they do, they will be very lucky indeed, but a new and expanding field is opening up, with collectable items of all sorts coming on to the market and providing a hobby which many can enjoy.

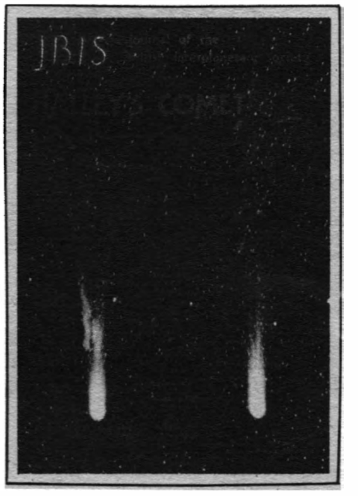
All this has prompted me to put pen to paper and to describe some of the results of my enquiries in an article to appear in *Space Education*.

Halley's Comet

Our normal suave exterior collapsed, momentarily, on reading the September 1984 issue of the "Halley's Comet Watch Newsletter" commenting on the January 1984 "Halley's Comet issue of *JBIS*". At the risk of blushing profusely I quote two extracts:

> "By reading this issue of *JBIS* completely, one could learn just about everything there is to know about Halley's comet. We found the issue even more comprehensive than some of the books currently available..."
>
> "Editor L.J. Carter and The British Interplanetary Society can be proud of the masterpiece they produced in the January 1984 issue of their Journal. If you want to experience "Halleymania" during the next two years as a fully-informed participant, then you should take the time to read this publication from cover to cover."

Members who would like to secure this *JBIS* issue as a souvenir (at £2 or $4, post free) should order without delay now as only a few are left. However, some completely new ground will be trod this year when we publish the papers by Dr. F.R. Stephenson on the early Chinese records of the appearances of Halley's comet from prehistoric times to the Middle Ages. As far as I know, this has never been written up before so a really fascinating account of the comet, as seen through Eastern eyes, will emerge for the first time. Dr. Stephenson has even gone one stage further than merely providing the text: he has prepared a whole series of maps showing the path of the comet in the sky for each return, as it would have appeared to these early observers.



The cover of the January 1984 'Halley's Comet' *JBIS* special issue. A few copies are still available at a cost of £2 ($4) each, post free.

Sign of the Times

The Society recently acquired a "calendar medallion' for the year 1758. The purpose of such medallions was to provide a guide to the days of the month, as well as such other useful information as could be included near the rim e.g. dates of the old Quarter Days. This one is particularly interesting because 1758 was the year when Halley's comet was due to make its first predicted return, an event awaited with mounting excitement for, if comets really did move in elliptical paths, their days as harbingers of fire, death and disease were numbered.

The occasion obviously rubbed on to "D. Silk. Astron." the maker of the medallion - for he has engraved in the margin the words "This year expect the Comete Without Danger."

Halley's comet was actually rediscovered in the Christmas of that year.

Generally Sunny...

Not just a natural disposition but the weather we expect to encounter during our South African trip to see the return of Halley's comet. Other surprises will be in store, too, with the Milky Way as a brilliant white band, almost dazzling, the Coal Sack - and Orion upside down!

Accommodation will be in first class hotels, except during the visits to Kruger National Park and Hazyview, where accommodation will be in rest houses. For the greatest convenience of all, it has now been decided to restrict the numbers participating to not more than 40 i.e. just one coach.

A detailed itinerary for members planning to go and is now available on request.

A portent of things to come took the form of Mr. Glasheen of Tetrovision Productions, collecting information for a two-part film entitled "Halley's Comet to Australia." The first was to show returns of the comet up to 1910 and the second to include not only the

production and launch of Giotto but also a record of the scientific results, and thus provide a complete coverage.

The Premiére will probably be in the new Space Theatre being built in Paris which, with the one just completed in the Hague, now brings the total of Space Theatres to about 15. We haven't anything like this in the UK though a good site exists at Greenwich, near the complex of the old Greenwich Observatory buildings and the National Maritime Museum.

Arc-lights

Deane Davis has thrown new light on the perils of public speaking. His occasion was back in the days following the successful Surveyor flights. Those involved were much in demand as public speakers. Briefings for particularly important VIP's took place in the Convair Presentation Room. On this occasion, Deane was deputed to do his stuff and found himself standing in the spotlights before no less than the President of Convair and a galaxy of Serving Officers.

At that time polyesters were being introduced into mens clothing. These early materials had a habit of unravelling though, with care, offending loose threads could be burned off quickly with a cigarette lighter, the trick lying in the ability to control the flame.

Deane was wearing a new pair of these 50% polyester trousers. During a lull in the proceedings he noticed a thread spilling out from his trousers so he reached down to give it a quick blast with his lighter. At that point a slide came on which read, in large red letters "Launch." For effect, Deane bellowed out the word. Unfortunately, it was accompanied by a sheet of flame belching up from his trousers, with the result that most of his audience found themselves beating out the flames with their caps. Luckily, he was wearing good English woollen stockings at the time.

As the smoke cleared and with the smell of singed fabric still in the air, Deane finished his talk and stood at the door to say "Goodbye" to his audience. They left in silence. The last to go, was a sympathetic Colonel.

He covered Deane's singed hands with his own singed hands and whispered *"Joan, hang in there!"*

[*Joan of Arc was burnt at the stake*—Ed.]

Lectures

With the advent of TV and video the heyday of the public lecture has probably now gone, though exciting events many of them were. One curious lecture I undertook was to a deaf audience. This seemed to present problems but they were overcome by an "interpreter" who translated the talk into sign language. My normal gobbledegook increases with enthusiasm and here the audience became so enthusiastic that the arms of the interpreter flailed like windmills as he put the message across.

To what extent he succeeded I never discovered but, beyond doubt, the audience gleaned sufficient to know what it was all about, as evidence by a cascade of questions afterwards.

In retrospect, this was probably one of my most enthusiastic audiences, yet they probably hadn't heard a word I said. If there is a moral in this, please don't tell me.

Taking up Spacc

The good offices of Andrew Matthewman alerted us to the possibility of obtaining a one-eighth scale model of the Shuttle. This worked out to a craft about 15 ft long, 10 ft wide and weighing 3 cwt, mounted at an angle on an alloy frame built for and owned by the Hepworth Iron Company of Sheffield.

Almost, but not cuite. The ⅛th Shuttle model proved to be just too much for our HQ. *The Yorkshire Post*

The opportunity was not one to be missed, particularly as there was free delivery, too. More good news was that the owners were prepared to donate the model to us. The bad was that we hadn't got the space for it and it was too heavy for us to manoeuvre.

Like fishermen, we can now always describe the really big one that got away.

Music of the Spheres

Cheerfully ignoring all warnings that I was tone deaf (even stone deaf, when it suits me) Doug Girling found a sizeable quantity of pro-space songs and "since the BIS has a reputation for promoting space awareness through its past involvement with science fiction" he belaboured me with a gift - in the form of several tape recordings.

I listened with mixed feelings, in view of some of the titles e.g. "Space heroes and other Fools," "Hymn to Breaking Strain" and "One Way to Go," though "Apollo Lost" brought on a slight touch of nostalgia.

No wiser than before, I consigned the lot to Wally Horwood whose claim to fame rests on the fact that he wrote a book about Adolf Sax, the developer (if that's the right word) of the saxophone. Opening it at random the other day, I read that Sax advocated an enormous Saxophone as a weapon of war, either to deafen the enemy or blow them back the way they came. I can't remember exactly. Wally sent back a glowing testimony.

So there you are. We space folk now have a space lore.

Society Motto

Readers will be relieved to know that I have found at last, a Society motto which satisfactorily sums up its aims, philosophies and acts - all at the same time.

It wasn't far to look: actually it appeared in the 'Secretary's Desk' for November. The motto comes from H.G. Wells' "Things to come" and simply says:

"The Universe, or Nothing."

There is little left unsaid. I feel sure the late Harry Ross, who first sparked off the discussion, would have approved of the choice.

BOOK NOTICES

Conquest
D. Baker, Windward Books (WHS Distributors), St. John's House, East St, Leicester LE1 6NE., 1984, pp.191, £9.95.

The author, well known to *Spaceflight* readers for many years, has produced a well-written, concise account of the Space Age for the general reader. He covers, in six chapters, the origins and basics of astronautics, the first steps in space, the exploration of the Moon and planets, space stations and the Shuttle, concluding with 10 appendices listing the world's rockets, space flights and astronauts.

It is not a book for the space enthusiast alone but an attractive volume to be read by the layman wishing to know more about space.

Entering Space - An Astronaut's Odyssey
J.P. Allen, Orbis Publishing Ltd, 20-22 Bedfordbury, London WC2N 4BT, 1984, 223pp, £15.

J.P. Allen made his first journey into space in November 1982 on the fifth flight of the Shuttle, *Columbia*. Here he provides a first-hand insight into manned space travel by providing a detailed account of the Shuttle flight from the tension of the countdown and launch to the challenges of living and working in space and then the dramatic descent and landing.

The book is particularly noteworthy for its collection of over 200 colour photographs, many not reproduced elsewhere and which dominate the book. To be fair, the book ranges far beyond the Shuttle flight alone, insofar as an extra chapter has been inserted on both manned and unmanned exploration of the Solar System.

Atlas of the Night Sky
S. Dunlop, Newnes Books, 84-88 The Centre, Feltham, Middlesex TW13 4BH, 1984, 80pp, £4.95.

This is a large-format atlas for the amateur astronomer showing the positions of the various constellations in the night sky. It includes a complete series of charts for both the northern and southern hemispheres for the Epoch 2000: most charts, up to now, have been based on the Epoch 1950.

The volume also contains descriptive text for all 88 constellations, arranged in alphabetical order. There are several practical sections on observing the Sun and Moon, including a specially-drawn lunar map.

The section on the planets shows how to plot their positions until the year 2000, and concludes with a chart showing the path of Halley's comet from November 1985 to May 1986.

The Society (with its address) is listed in an appendix, though neither *Spaceflight* nor *Space Education* (nor even *JBIS!*) appear in the list of relevant magazines though all three feature extensive material on planetary and stellar studies.

International Security Dimensions of Space
(Eds) U. Ra'anan and R.L. Pfaltzgraff, Jr., CLIO Distribution Services, 55 St. Thomas' Street, Oxford OX1 1JG, 1984, 324pp, £33.84

The object of this volume is to point out that, despite the current success of the Space Shuttle, the US still faces major weaknesses in its ability to make effective use of outer space - whether for commerce or national security.

The implications of this are so enormous that a number of contributors representing a wide spectrum of American thought have provided papers which revolve around such topics as space as a high frontier for strategic defence, the technological and operational aspects of space systems, and space as a military environment and as an area where policy decisions must be made on matters of security.

It it now commonplace for observations and communications to be conducted *via* space, some operated for civilian use and others for military purposes. Deployment in Earth orbit of weapons of mass destruction is prohibited by treaty, even though this agreement is largely symbolic because it is not clear, at this stage, whether nuclear weapons deployed in Earth orbit possess real military value. Even so, the treaty mentions no other weapons e.g. anti-satellite weapons.

Over the next two decades manned bases in Earth orbit, from which all kinds of space operations will be conducted, will undoubtedly emerge both from the US and USSR. If such programmes could be internationalised at an early stage, the risk of usage for military purposes would probably be greatly reduced.

Contributions in the volume review many aspects of such developments, ranging from near-Earth to slightly more exotic areas.

The comment on past UK space activities seems very apt. It runs: "In the first decade or so after World War II, Britain established an early lead in the development of large boosters but it failed to capitalise on this leadership and, during the 1970's fell behind France and the Federal Republic of Germany in its commitment to space activities. Now, after a period of comparative apathy on the subject, the British Government is showing new vitality concerning space projects in the 1980's and 1990's..."

This book provides abundant further reasons why such a course is highly desirable.

Saturn
Ed. T. Gehrels and M.S. Matthews, University of Arizona Press, 1615 E. Speedway, Tucson, Arizona 85719, U.S.A., 968pp, 1984, $37.50.

A team of 77 authors, most of whom were participants in the Pioneer and Voyager missions to Saturn, present a wealth of data on their analyses regarding Saturn's atmosphere and interior as well as its magnetosphere, rings and satellites.

The Saturn system is undoubtedly the most complex in the solar system. Indeed, one might be forgiven for thinking that the recent probe discoveries have added more to its complexity than was hitherto known. Its unique character was recognised with the discovery of its rings by Galileo in 1610 and, as time went by, it was established to be a giant gaseous planet encircled by three main rings containing centimetre-sized ice-covered particles and a number of satellites. One of these, Titan, was known to be a planetary-sized body with a substantial atmosphere containing methane, which explains why three chapters in the book are devoted to this satellite alone. The flybys in 1979, 1980 and 1981 added an enormous amount of additional information, with the result that, incidentally, the orbits of no less than 17 satellites are currently well known besides several others which have been rather less well-determined.

This book is a compendium of all that is currently known about the planet and its satellites and, although highly technical in parts, is easily the best compendium on the subject currently available.

Annual Review of Astronomy and Astrophysics Vol. 22
Ed. G. Burbidge, *et al*, Annual Reviews, Inc., 4139 El Camino Way, Palo Alto, California 94306, USA, 1984, 635pp, $47.

Once again we welcome this annual compilation of a selection of essays on important developments in astronomy during the past year or so. The present volume contains 20 such contributions though the first contribution is more in the nature

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Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

of an autobiography of Dr. Greenstein. As previously, the wealth of contributions is concerned mainly with developments in stellar astronomy and with our Sun, in this respect, considered more as a nearby star and rating three contributions. Particularly interesting is the contribution on alternatives to the "Big Bang." The latter has reached such acceptance lately that one was hard put to find anyone left willing to put forward some alternative hypotheses. Fortunately, several other choices appear in this contribution.

All contributions are eminently readable but do not pander to the current vogue for plenty of pictures, full colour, low information-content and not much reading matter. What we have here is a collection of contributions which put across the results of substantial research. As such, they are directed to readers who need solid text without any frills.

AAS PUBLICATIONS
All are available from Univelt Limited, P.O. Box 28130, San Diego, CA 92128, California, USA.

Space and Society - Challenges and Choices
Vol. 59, Science and Technology Series, Eds. P. Anaejionu, *et al, 442pp, 1984,* h/c $55, s/c $35.

Proceedings of a conference held 14-16 April 1982 at the University of Texas at Austin. Subjects included are American government and space, political economics and space, foreign space programs, space applications and the future.

Space Safety and Rescue 1982-3
Vol. 58, Science and Technology Series, Ed. G.W. Heath, 1984, 378pp, h/c $50, s/c $40.

Based on symposia of the International Academy of Astronautics held in conjunction with the 33rd and 34th International Astronautical Congresses, Paris, France, Sept. 27 - Oct. 2, 1982, and Budapest, Hungary, Oct. 10-15, 1983. An update of space safety and rescue technology including orbital debris hazards, astronaut and systems safety, psychology and safety of weightlessness, law applications and medical-biological radiation hazards in Earth orbits. Worldwide disaster response, rescue and safety employing space-borne systems includes satellite search and rescue systems, international systems, satellite emergency communication systems, and much more.

Guidance and Control 1984
Vol. 55, Advances in the Astronautical Sciences, Eds. R.D. Culp and P.S. Stafford, 1984, 500pp, h/c $60, s/c $50, Microfiche Suppl. $15.

This volume is based on the Annual Rocky Mountain Guidance and Control Conference held 4-8 February 1984 at Keystone, Colorado. It includes sessions on international space programs, storyboard papers/display, rendezvous, docking and orbit servicing, vehicle guidance, control, and payload effects, and recent experiences. These annual meetings provide a forum for recent and new developments in guidance and control.

Astronomical Objects for Southern Telescopes
E.J. Hartung, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 138pp, 1984, £8.95

This is the latest edition of a reference book which has enjoyed enormous popularity as a handbook for amateur observers of the Southern sky. Five introductory chapters discuss, briefly, the various types of objects available for study, followed by tables and descriptions of over 1,000 of the more interesting and attractive objects between the South Pole and 50° N declination.

The book is primarily an aid to observation, hence many references to the equipment actually used by the author over many years.

Mathematical Astronomy in Copernicus' *De Revolutionibus*
N.M. Swerdlow and O. Neugebauer, Springer-Verlag GmbH, Heidelberger Platz 3, Postfach, D-1000 Berlin 33, Germany., 1984, 711pp (In two parts, not available separately), $88.80.

Copernicus was born in 1473 at Torun, then an important island city of the Hanseatic League. Doubtless he learned astronomy at the University of Cracow which he attended until the age of 22 for his earliest dated observation (an occulation of Aldebaran) was made on 9 March 1497. His new theory was conceived about 1510. By the early 1530s knowledge of this was circulating in Europe and was soon to reach the Vatican. The astronomer Clavius (1537-1612) was a supporter of the Ptolemaic system and an opponent of Copernicus. In his *In Sphaerum Ioannis de Sacro Bosco Commentarius* he was apparently the first to accuse Copernicus not only of having presented a physically absurd doctrine but also of having contradicted numerous scriptural passages, though the friendship between Clavius and Galileo began when Galileo was 23, remained unimpaired through Clavius' life.

This important work is a technical exposition of the mathematical astronomy of *De Revolutionibus* and its relation to earlier works in the Ptolemaic tradition known to Copernicus. It is concerned with the object, development and the limitations of *De Revolutionibus* by setting out as completely as possible the demonstrations which it presents. The first part of the current work contains the printed text, the observations and reduction of observations. The second part contains a list of symbols, parameters and all 204 figures.

De Revolutionibus was published in Nurenberg in 1543. Except for the inclusion of a star catalogue at the end of book two, the first two books of *De Revolutionibus* correspond to the order of subjects in Ptolemy's *Almagest* e.g. the first 11 chapters of book one are devoted to a general description of the Universe and of the location and motions of the Earth. Here, Copernicus attempts to defend the motion of the Earth, specifically its daily rotation, against objections. His argument, spread through several chapters, is that the Earth is spherical and rotates uniformly around its axis.

DO YOU REMEMBER?

25 Years Ago...
21 January 1960. Rhesus monkey Miss Sam is launched aboard Little Joe 1B for a Mercury spacecraft launch escape system test. Both capsule and passenger were recovered safely following the 8½ minute flight.

20 Years Ago...
19 January 1965. The unmanned Gemini 2 completes a successful sub-orbital flight to qualify the spacecraft for human occupants.

15 Years Ago...
11 February 1970. Japan becomes the fourth nation after the USSR, USA and France to launch an artificial satellite. The 24 kg satellite, Ohsumi, was an engineering test for the launching of a scientific payload.

10 Years Ago...
8 February 1975. A Soviet party, including cosmonauts Leonov and Kubasov, visit Kennedy Space Center for a three day tour. They inspected the Saturn 1B and Apollo CSM to be used during the Apoll-Soyuz mission later in the year.

5 Years Ago...
14 February 1980. NASA's Solar Maximum Mission satellite is launched into a 566 km orbit to observe solar flares at the peak of the Sun's 11 year cycle. It was the first satellite to use the multi-mission modular spacecraft bus to allow in-orbit refurbishment - as successfully demonstrated during Shuttle mission 41C in April 1984.

K.T. WILSON

EXPLORING THE MAGNETOSPHERE

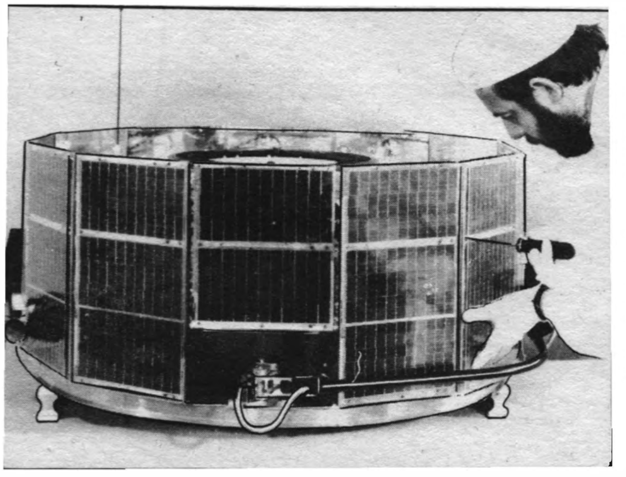
The Society has invited a Rutherford Appleton Laboratory scientist to discuss a current space experiment that is providing a wealth of new data. Dr. Duncan Bryant, the AMPTE United Kingdom Satellite Project Scientist, will describe the background to this exciting project and give an initial survey of the basic results.

AMPTE (Active Magnetosphere Particle Tracer Explorer) is a three-satellite programme launched last August and designed to explore the complex region of charged particles and magnetic fields (the magnetosphere) that envelops the Earth out to distances beyond 100,000 km. This region, as well as being of great scientific interest, protects Earth from the solar wind.

Built jointly by the Rutherford Appleton Laboratory in Oxfordshire and the Mullard Space Science Laboratory of University College London, the UKS satellite is the British contribution.

The German 'Ion Release Module' has ejected canisters of barium and lithium tracer elements for detection by UKS and the US 'Charge Composition Explorer' patrolling much nearer to Earth. Artificial aurorae and a comet have thus been created for study by scientists.

Admission to the talk at Society HQ on **1 May 1985**, 7.00-9.00 p.m. is by ticket only, available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose s.a.e.



The British UKS satellite of the AMPTE project. *RAL*

SURPLUS LIBRARY BOOKS

We have a number of surplus Library Books and Reports on astronomy and space that are being offered at very low prices. To secure a list of those available, simply send a reply-paid envelope with your request to The British Interplanetary Society, 27/29 South Lambeth Rd, London SW8 1SZ. If you spend £20 or more you may deduct a 10% discount.

Please enclose a 20p stamp and specify if you require the Book List, Technical Report List, or both.

BADGES

A range of badges with the Society's motif is available.

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A special metal car badge adds that distinguished look to any vehicle for only £3 (£3.50 or $6 abroad).

It would be clearly to your advantage to

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Application form and prospectus obtainable from.

The Assistant Secretary
British Astronomical Association,
Burlington House, Piccadilly, London, W1V 0NL.

The Library Committee is endeavouring to build up its collection of first-day covers on

SPACE AND ASTRONOMY

We would welcome hearing from any members with items like this for disposal and willing to give or sell them to the Society.

All manner of items will be considered but the Society has a particular interest at present in securing covers ranging from pre-war launchings to the manned Mercury and Gemini flights.

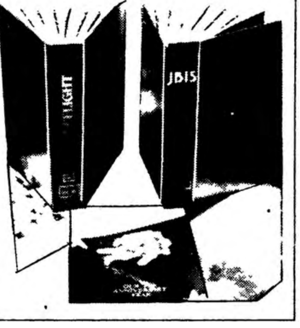
Please contact the Executive Secretary if you think you can help.

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices, please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

BINDERS

The ideal way of keeping your magazines in perfect condition. *Spaceflight* binders carry *BLUE* covers, those for *JBIS* are *GREEN*. Gold lettering on the spine identifies the magazine, volume number and year. Cost: £5 ($8 abroad) each. Note: *JBIS* binders fit post-1976 volumes.



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Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01–735 3160.

NOTICES OF MEETINGS

Film Show
Theme: **MOMENTS IN HISTORY (PART 2)**

The second of two meetings devoted to historical space films will be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **6 February 1985**, 7.00-8.30 p.m.

The programme will include the following:

(a) A Man's Reach Should Exceed his Grasp

(b) Small Steps, Giant Strides

(c) A Moment in History

(d) Blue Planet

(e) Meteosat

Admission is by ticket only. Members wishing to attend should apply in good time, enclosing a stamped address envelope.

Lecture
Theme: **COMMERCIAL LAUNCH VEHICLES**
By G.M. Webb

The context in which Europe will be competing commercially using its post-Ariane 4 series of launcher will probably be very different from the present situation; the viability of the various options open in the mid-1990's will be discussed.

To be held in the Socity's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **20 February 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Symposium
Theme: **EUROPE-US SPACE ACTIVITIES**

The **1985 Goddard Memorial Symposium**, in conjunction with the **19th European Space Symposium**, will be held at the NASA Goddard Space Flight Center, Maryland, USA on **28-29 March 1985** organised by the American Astronautical Society and co-sponsored by The British Interplanetary Society in association with other Societies.

Offers of papers are invited. Futher information is available from the Executive Secretary and registration forms will be available in due course.

One-day Symposium
Theme: **SPACE STATIONS**

A one-day symposium on the obove theme, considering the technology and applications of Space Stations, will be held in the Society's Conference Room on **17 April 1985**.

Offers of papers are invited. Potential authors are requested to contact the Executive Secretary, at 27/29 South Lambeth Road, London SW8 1SZ.

Lecture
Theme: **PLASMA PHYSICS IN SPACE**
by Dr. D.A. Bryant
Rutherford Appleton Laboratory

Results from the three-satellite AMPTE mission, launched in August 1984 to explore by revolutionary new techniques the interaction of the solar wind with the Earth's magnetosphere and the comet-like behaviour of injected plasma clouds, will be discussed.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **1 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture
Theme: **COHERENT LIGHT FROM SUPERNOVAE**
By A.T. Lawton
President of the Society

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **15 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

One-day Forum
To be held in the Society's Conference Room, 27/29 South Lambeth Rd, London, SW8 1SZ on **Saturday, 1 June 1985**, 10.00 a.m. to 5.00 p.m.

Topic: **THE SOVIET SPACE PROGRAMME**

Subjects will include :

History of the USSR Lunar Programme

Cosmonaut Update

Soviet EVA Experiments

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:

6 Feb 1985	20 Feb 1985
3 Apr 1985	1 May 1985
15 May 1985	12 Jun 1985

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

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88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-3
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По подписке 1985 г.

astronaut payload specialist visits BIS

Published by
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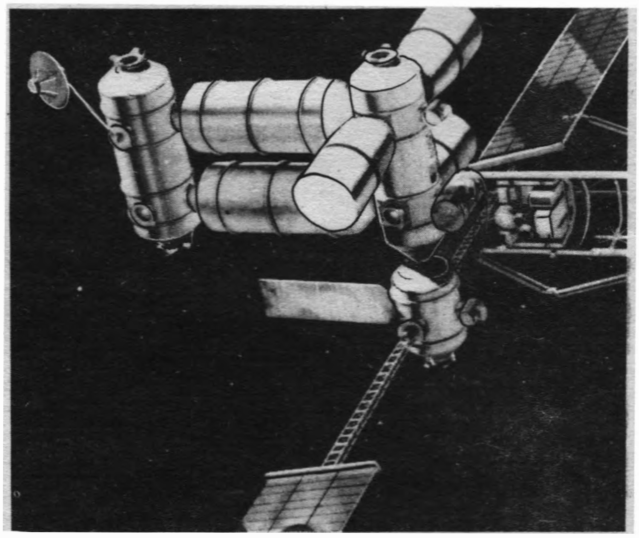
MARCH 1985
VOLUME 27 NO. 3

SPACE STATION PLANS

The US Space Station is the next major manned space project of the western world, with initial operations in orbit expected in the early 1990's. Plans for participation are being considered by most European countries, including the UK. Our Society, which has long advocated permanent manned bases in space, will contribute further to the discussions by providing updated reviews at a one-day symposium. The date is 17 April 1985, the venue HQ. A provisional list of papers to be presented by a panel of international speakers will include the following:



1. **'European Space Station Overview,' by F. Longhurst (ESA).**
2. **'Space Station Platform - Overview,' by Dr. R.C. Parkinson (BAe).**
3. **'User Requirements for Space Stations,' by I. Franklin (BAe).**
4. **'Space Station Pressure Compartment,' by Prof. Valleriani (Aeritalia).**
5. **'Application of Propulsion Modules to Space Station Infrastructure,' by D. Gilmour (BAe).**
6. **'Orbital Replacement Units for Space Stations,' (Provisional).**
7. **'Assembly and Maintenance of Space Stations,' (Provisional).**
8. **'European Overview of the Space Station Proposals,' by R. Gibson.**

The Symposium will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, England on 17 April, 9.30 a.m. to 5.30 p.m. The registration fee is £15 (non-members £17). Forms are now available from the Executive Secretary at the above address. The places remaining are limited so early application is advised.

1985 SUBSCRIPTION FEES

There is good news for all members: fees for 1985 will remain unchanged from 1984 in spite of rising costs.

Direct Debit Scheme

Our old Bankers Order system has been phased out. Direct Debit slips are now available from the Executive Secretary but, since they will not come into operation until 1986, a separate remittance for 1985 will have to be made.

Amounts payable for the calendar year January-December 1985 are as follows:

RATES

Members	Sterling	US Dollars
Under the age of 18 years	£16.00	$26.00
Between 18 and 20	£18.00	$30.00
21 years of age and over	£21.00	$36.00
Fellows	£23.00	$40.00

Age Allowance

A reduction of £4.00 ($6.00) is allowed to members of every grade over the age of 65 years on 1 January 1985.

JBIS and *Space Education*

The additional subscription payable for *JBIS*, where required as well as *Spaceflight*, is £20.00 ($34.00). For *Space Education*, it is £4.00 ($6.00).

Methods of Payment

Europe

(a) Please pay in sterling with a cheque which shows a UK address, where it can be paid.

(b) Cheques drawn in sterling payable at a bank in Europe must include £2.00 to defray charges and collection costs. Eurocheques have no charges *only* if the account number is written on the back.

(c) Banks which remit directly to the Society must be told to see that the sum is transmitted *free of deductions*.

(d) Remittances from Europe are best made by GIRO. Our GIRO account number is 53 330 4008.

USA and CANADA

(a) US dollar cheques can be drawn on a Bank which gives an address in the United States or in the UK. US dollar cheques drawn elsewhere need to be increased by $8.00 to cover collection charges.

(b) US dollar notes are accepted.

(c) US or Canadian money orders can only be accepted if *expressed in Sterling*. Internal money orders from these countries i.e. those expressed payable in dollars will be returned as they cannot be cashed in the UK.

(d) Canadian bank remittances may easily be made in sterling drawn on their UK agents. If payment is made in Canadian dollars the current exchange rate may be used, plus the addition of 8 Canadian dollars to cover exchange and collection charges.

spaceflight

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Founded 1933 *Incorporated 1945*

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Editor
G. V. Groves

Managing Editor
A. Wilson

Assistant Editor
L. J. Carter

CONTENTS

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SHUTTLES AND SPACE STATIONS

Two very important events for the future of the projected US Space Station occurred in late 1984:

1. An American President was re-elected with one of the largest landslide victories in US history; in fact, the largest since George Washington ran unopposed in 1792.

2. The Shuttle *Discovery* provided excellent proof that such vehicles are true spaceships for launching, retrieving and repairing satellites. This particular concept was a fiction writer's dream for many years until a group of astute engineers and insurance financiers realised that the repair and the rescue of 'Solar Max' meant that the 'Palapa' (owned by Indonesia) and the 'Westar' (owned by Western Union) communications satellites could be rescued, repaired and resold. For the first time a Shuttle craft returned two extremely valuable cargoes it had not originally carried to orbit. It should not be forgotten that Man's hands played a crucial role - tools did not work at a critical stage.

These two events are connected, since space programmes take, typically, up to 12 or more years to come to fruition. The result is that the success of the present-day Shuttle rests on the joint ideas of people who, back in 1968-9, began to plan the follow-on to the then successful Apollo programme. Some were dedicated to the idea of selling space on a commercial basis. This could not be done with the Saturn 5 or Skylab systems, even though the latter could have been developed to produce a medical harvest similar to that reaped by Salyut.

A vastly different vehicle was required, one that was reusable and, therefore, largely aerodynamic. This was the Shuttle in essence, with several hundred configurations studied over the years. Each time performance and costs were reviewed and traded off with relentless pressure. Far from shelling out thousands of millions of dollars freely, it was difficult to prize even $10 out of the review panels if it was considered the item could be discarded.

There were those who 'knocked' the project and jeered every time Shuttle motors failed or heat resistant tiles fell off, or complained that the Shuttle was using valuable money which, they felt, should be spent to better effect on e.g. unmanned satellites.

Finally, the first Shuttle blasted into space and it became clear from the beginning that the basic idea was sound. Although there have been several setbacks, its basic soundness has been

Concluded on p.144

COVER

BIS Fellow Charles Walker, payload specialist astronaut aboard Shuttle 41D last June, paid a visit to the Society's headquarters recently. He tells us that, as the McDonnell-Douglas representative for handling the electrophoresis equipment in orbit (see *Spaceflight*, January 1985, pp. 36-42), he expects to fly aboard the Shuttle again this year. *BIS*

SPACE '84

THE FUTURE OF MANKIND

Space '84, held at Brighton on 16-18 November 1984, was organised with some trepidation at first. Would it be as good as Space '82? Could we achieve the same atmosphere of friendliness? Would the theme prove so attractive and the speakers so good? Would it be possible to hit the same high note again?

We need not have worried. In the event, Space '84 was a resounding success, up to the standard of its predecessor in every way and vouched for by all 240 who attended.

Programme

The Space '84 proceedings began with a welcome to Brighton by the Mayor and Lady Mayoress, followed by a response by Mr. Martin Fry, Vice-President and Chairman of the Programme Committee, who was standing in to replace our President, Tony Lawton, who was indisposed.

The theme of the meeting was 'Space: The Future of Mankind.' A total of 24 speakers addressed themselves to this subject under various headings and over a wide spectrum e.g. those speaking on *New Frontiers* and *Discovering the Universe* set the scene by looking at near and far space. The next two sessions, *Foothold in Space* and *Energy and Resources*, surveyed the scene as it appears in the light of our present resources, while two sessions on *Advancing Frontiers* showed how space probes were extending our knowledge further into the Solar System and beyond. Two further sessions concluded the meeting, the first on *The Future of Mankind* evaluated human performance in both physical and mental terms relating to both manning a Space Station and colonising distant worlds. The final session, under the intriguing title of *Workshop*, was largely concerned with the interface between nations which led to cooperative projects.

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FROM THE DESK OF THE CHANCELLOR
UNIVERSITY OF MORATUWA, SRI LANKA

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Arthur C. Clarke
B.Sc., F.R.A.S., F B I.S
Fellow of King's College London

දුරකථන 94255
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Tel 94255
Cable - Undersea Colombo

Dear Sir,

Congratulations on Space '84! Although I cannot be present personally, much as I would like to be, I know it will mark another step forward in the Society's history.

The theme "Space - The Future of Man" is one I find particulary exciting. After all, it has been the subject of every science fiction writer from Lucian of Samos in AD 160 onwards..... and its truth is becoming every day more apparent.

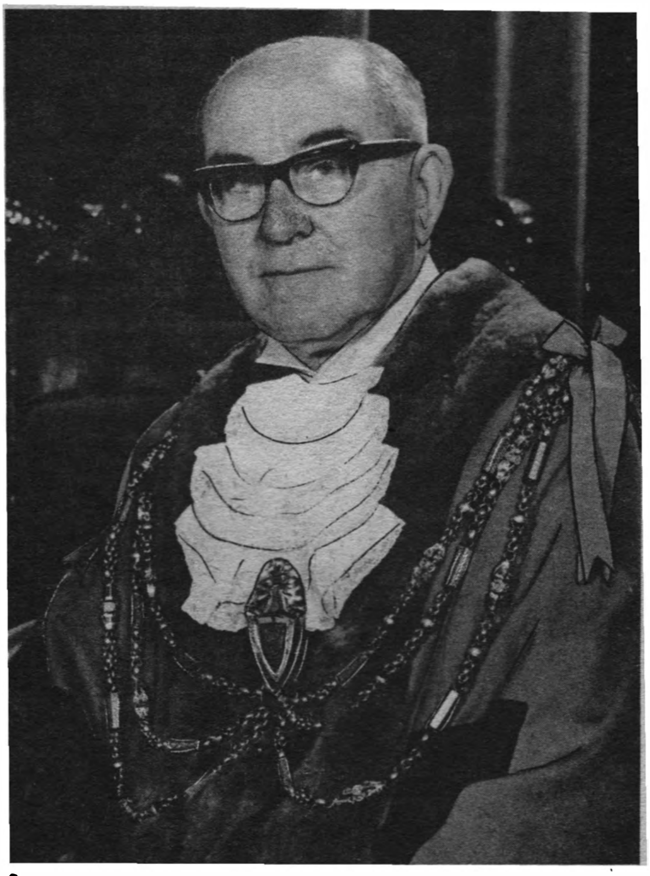
The days of tentative scientific exploration of near-space are passing rapidly; the dawn of exploitation - hopefully in the best sense of the word - is almost here. More and more human beings will venture into space; this century may see the first child born beyond the Earth.

Throughout its history the Society has argued that the Space Station is a stepping stone to the Moon - and that both are the doorways to manned exploration of the entire Solar System. This is now becomning more and more widely accepted.

To echo Tsiolkovski's famous analogy, the Earth is a cradle which, by the 21st Century, Man will have outgrown. Soon, even the most visionary of our present thoughts will seem commonplace - as we adapt to our new environment and take our first steps on the road to the stars.

Arthur C Clarke

ARTHUR C. CLARKE



Space '84 was opened by The Worshipful The Mayor of Brighton, Councillor John Blackman.

Particularly interesting was an extra paper presented by Wubbo Ockels, Spacelab payload specialist, who also answered a host of questions about his upcoming Shuttle flight.

Most exciting was the broad-brush treatment of the subject given by many of the speakers. This, coupled with the wide-ranging nature of the topics, produced a clear vision of the future, as it would affect Man's exploration of the Universe. Philosophy, advanced ideas, imaginative thoughts and technical know-how jostled for attention, yet the audience was never 'lost.' The appeal of the topic was over-riding. As before, printed versions of some of the papers will appear in the Society's magazines, but these will be relatively few in number compared to the feast of data served up at Space '84 itself.

All the meetings were held in the Foyer Hall in the Brighton Centre, bedecked for the occasion not only by first-rate exhibits from Marconi Space and Defence Systems, British Aerospace and Culham Laboratories but with the opportunity for participants to 'see' the weather *via* Meteosat 2 through the good offices of Feedback Instruments Ltd, who set up a ground receiving station in one corner. The back of the hall was enlivened by an ultra-large mural of the Solar System, loaned by Mr. P. Fisher, and the whole rounded off by an excellent selection of souvenir items, comprising books, slides, mission patches and a wide range of mugs, decanters and similar glassware impressed with the Society's logo and commissioned specially as a fund-raising source through the good offices of Western Glass International. All this was supported by the Society's normal saleable articles.

All the supporting facilities were provided, as usual, by our staff, who rose as one to head off problems as fast as they emerged, with the result that everything, on the surface at least, proceeded serenely.

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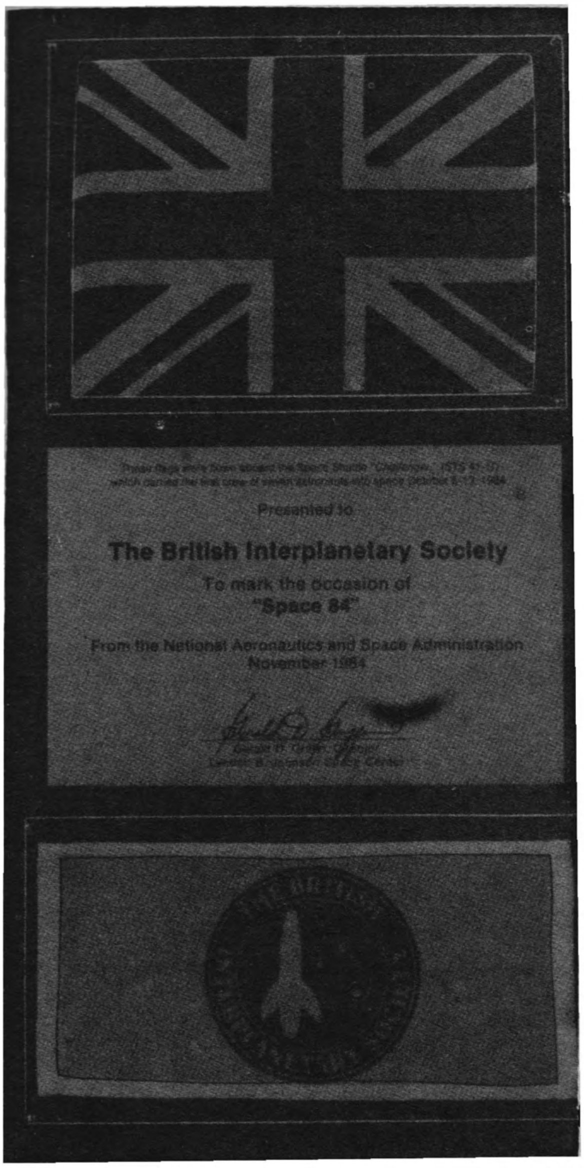
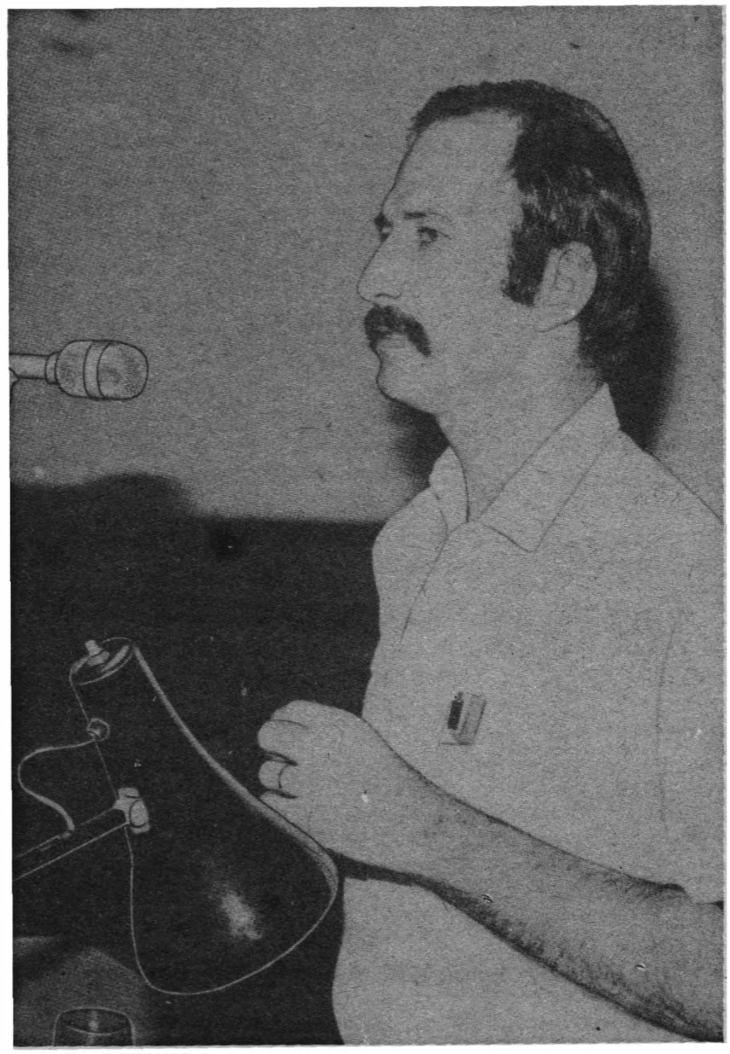




Spacelab D1 astronaut Dr. Ulf Merbold.

Dr. Ulf Merbold (right) and Dr. Dái Shapland, both of ESA.

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas
77058

NASA

AA

NOV 9 1984

Mr. Anthony J. Smith

Dear Tony,

The British Interplanetary Society flag and a UK flag that were flown aboard Shuttle mission 41-G have been appropriately mounted for presentation to the BIS membership at Space '84, being held at Brighton Center. I am pleased we were able to fly the organization's official emblem and know you and the other members will display it proudly. Please make the presentation on behalf of myself and all of the NASA and contractor employees who are responsible for our successful efforts in space.

I personally appreciate all of the support the BIS has given to NASA programs. Your commitment to informing your members on the international advancements of space research, technology and applications is apparent in the Journal of the British Interplanetary Society and Spaceflight; both valuable sources of information respected throughout the world.

I am also aware of your lectures, space study courses, technical symposia and international meetings held throughout the year, all contributing immensely to the understanding of all nations' efforts in space flight. These activities serve you well in achieving one of the Society's primary goals: to discuss national and international activities performed in space and to formulate forward-looking policies for the advancement of space exploration and exploitation.

We, here at the Johnson Space Center, thank you for the opportunity to be a part of your program, "Space -- The Future of Mankind." We will continue to assist you in every way we can in achieving the Society's goals. Please convey our thanks and appreciation to your membership for all of the support given us throughout the years.

Sincerely,

Gerry

Gerald D. Griffin
Director

Space '84 in action. From top left, clockwise: Dr. John Davies, Dr. George Mueller, Dr. William McLaughlin, Dr. Robert Parkinson, Sqn. Ldr. Richard Harding and Dr. Gordon Whitcomb.

Sir, I must write to thank you and the Council of the British Interplanetary Society very much indeed for the delightful evening at the Brighton Centre on 17 November.

It was a special pleasure to see you again, after so many years, and to know how vigorous and enthusiastic The British Interplanetary Society continues to be under your guidance.

I much enjoyed meeting Martin Fry (Society Vice-President) and so many other stalwarts of the Society, and altogether, it was a most enjoyable occasion. Thank you very much indeed.

SIR PETER MASEFIELD
Chairman, British Caledonian Airways

Sir, I very much enjoyed Space '84 and the great enthusiasm that was so evident amongst attendees. In fact, I have very rarely enjoyed a conference so much. I cherish my contacts with the Society and look forward to being able to support its activities in future.

Dr. H. JOYCE
Space '84 Speaker

Sir, A big thank you for a very interesting Space '84 weekend, thoroughly enjoyed by self and spouse! The organisation was evidently superb though, no doubt, a few panics were bubbling beneath the apparently smooth surface.

MRS M.E. MASON
Surrey

Sir, It's a weekend I'll remember for the rest of my life. I thoroughly enjoyed it, everything was marvellous.

MAX WHOLEY
Midhurst

Ladies' Events

As is usual on such occasions, the ladies had it good. Not only did they have a Civic Dance and Banquet to enjoy, of which more anon, but had two further events all to themselves. The first was a private tour around the Royal Pavilion, accompanied by the Chief Guide and with coffee and biscuits to follow. This was voted excellent by all concerned. The second was an all-day excursion with the first stop at the House of Pipes. This sounded most inappropriate for ladies but was actually something they enjoyed greatly. At that point, the original plan had been to decamp them in Arundel Castle but as it was closed for necessary renovations an alternative venue at Barnsgate Manor was selected instead. This was at the centre of a newly-emergent wine-growing industry being created in the UK, the idea being to get the ladies thoroughly soused while the rest of us considered the finer points of Man's destiny. How they got on we never really knew. After leaving the House the Pipes the coach vanished uphill towards the South Downs and was lost in mist.

Banquet speaker Patrick Moore and Space '84 attendee Claire Phillips.

Civic Dance

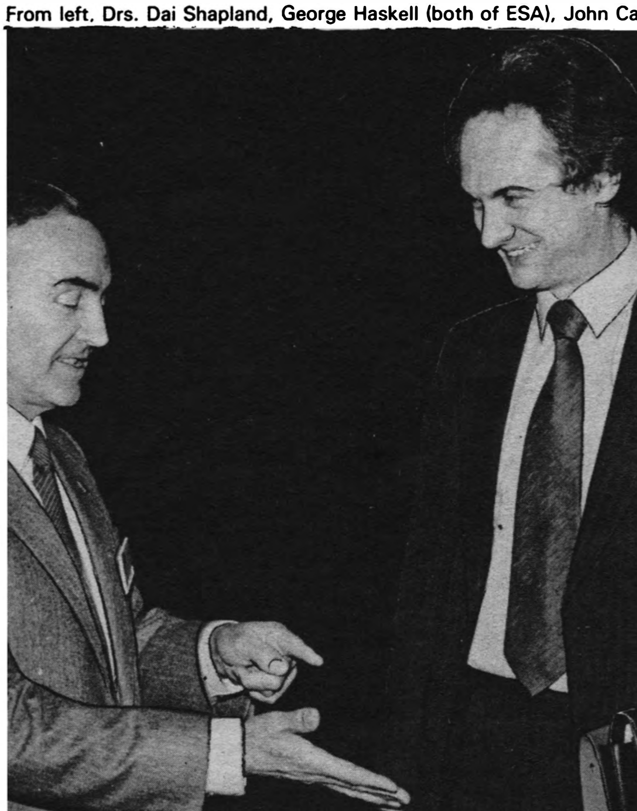
The Civic Dance and buffet reception put on by the Corporation of Brighton to welcome Space '84 participants also took place in the Foyer Hall, with band and singers specially engaged for the entertainment of both dancers and non-dancers alike. We were honoured by the presence of the Mayor and a number of Guests (some clearly still suffering from jet-lag) so a marvellous opportunity was created for conversation and enjoyment throughout the evening, so much so that we were hard put to persuade some of the late night revellers to leave, to allow sufficient time for the hall to be rejuvenated for the opening lectures the following morning.

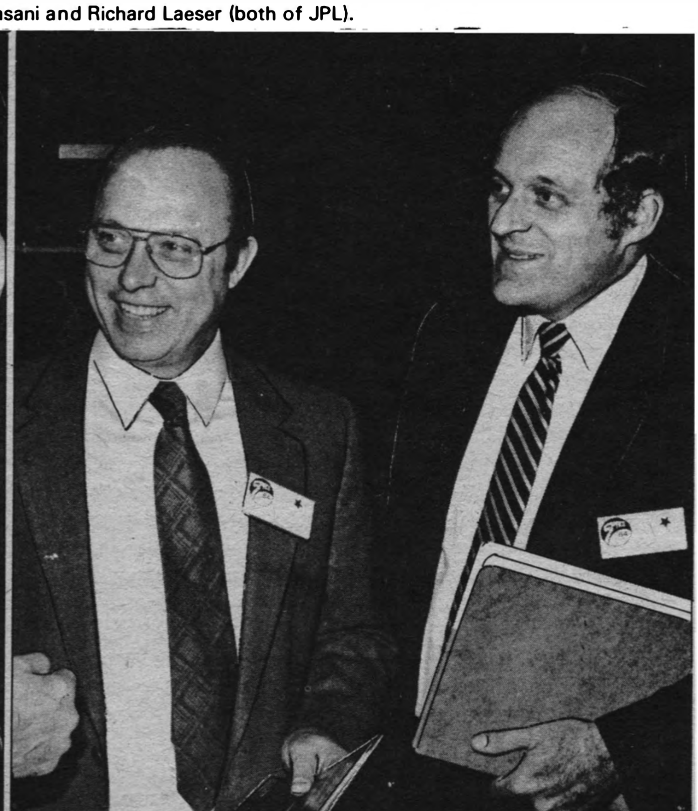
Banquet

There was no doubt that the Banquet was the highlight of the whole of Space '84. It was a simply superb occasion. Unlike Space '82, a change in plan had been made whereby the Banquet would also be held in the Foyer Hall, thus necessitating a quick-change from a meetings room to a banqueting hall in less than two hours. The staff set to with a will, with the result that the most pleasing effect was achieved.

After an excellent speech and the Loyal Toast, our Vice-President moved a Vote of Thanks to Brighton Corporation for their wonderful support which had done so much to make Space '84 so successful. Councillor Theobald (who had been Mayor during the Space '82 event and was now deputising for the Mayor at the Space '84 Banquet) responded in similar vein, adding how sorry he was that our President had not been able to be present and sending his best wishes. This was echoed by all present, with the result that a menu card was pressed into service to express these thoughts and signed, during the course of the evening, by practically everyone present.

From left, Drs. Dai Shapland, George Haskell (both of ESA), John Casani and Richard Laeser (both of JPL).





At that point the Vice-President introduced a number of Guests of Honour and expressed his particular pleasure in being able to welcome Dr. George Mueller, President of the International Academy of Astronautics and one who had contributed enormously both to the Apollo programme and to the origination of the Shuttle, and to Dr. John Casani, wishing him good luck on the forthcoming Galileo Jupiter probe, 'the last of the big ones.' He also introduced Dr. and Mrs Wubbo Ockels, adding his good wishes for a successful flight in the upcoming Spacelab D1 next autumn, and concluded with a welcome to Mr. Osman and Mr. Thomas who were, no less, two of our Executive Secretary's former school teachers.

The point was then reached for Presentations, at which, three wonderful events occurred. First was the reading of a message from a distinguished former Chairman of the Society, Arthur C. Clarke, sending his good wishes for the success of Space '84. This was most gracefully done. It was followed immediately afterwards by a superb presentation of a plaque on which had been mounted a UK flag *and the Society's flag,* both of which had been flown aboard the Space Shuttle *Challenger* (Mission 41G) which carried the first crew of seven astronauts into space on 5-13 October 1984. It was signed by Gerald D. Griffin, Director of the Lyndon B. Johnson Space Center and was accompanied by a message which was read aloud and warmly applauded. Finally, a third message was read, this time from the four prospective UK astronauts, expressing their goodwill and success for Space '84.

The Vice-President said that not only he had been overwhelmed by these expressions of kindness and courtesy but, looking around, he could see that everyone present had been equally thrilled. The Society was proud to receive such messages and would value them from now on as integral parts of the Society's history.

Councillor Geoffrey Theobald graced the Society's proceedings and bid participants welcome to Brighton.

He then welcomed with great pleasure three further distinguished guests, each of whom was to make a short speech. The first, Ted Mallett, Director of Applications of the European Space Agency, set the proceedings off to a rollicking start by describing the growth of acronyms [or A Confusing Row of Names You Must Simplify!] and indicating some of the effects that could result if the wrong letters were chosen and providing fictional (at least, we hope they were) examples of acronymese in the

Sir Peter Masefield, Chairman of British Caledonian Airways, replied to the Vice-President's toast of 'To Our Distinguished Guests.' Here is an extract:

I congratulate the Society, most warmly, on the foresight with which, 50 years ago (way back in 1933), it looked to the vision of the future in space. No nonsense then about merely getting to the Moon. No, the foresight and the vision were set much higher and further, as befits 'The British *Interplanetary* Society.'

Looking back on those earlier days, I recall with pleasure and appreciation some highly visionary and enthusiastic discussions with old friends who were some of the founders of the Society: Val Cleaver, Alan Slater, Kenneth Gatland, Arthur Clarke and, of course, our ever-youthful and immensely capable Executive Secretary, the great Len Carter, whom I rejoice to meet again this evening.

Prompted by them, I had the privilege of joining the Society some 37 years ago at the time when I was the Chief Executive of British European Airways. I remember discussing with Val Cleaver and Alan Slater, in 1949, the prospects for interplanetary flight and how long it might be before we, of BEA, might plan to launch an associated, long-range, Space-Transport company, perhaps to be called BEIA - 'British European *Interplanetary* Airways.'

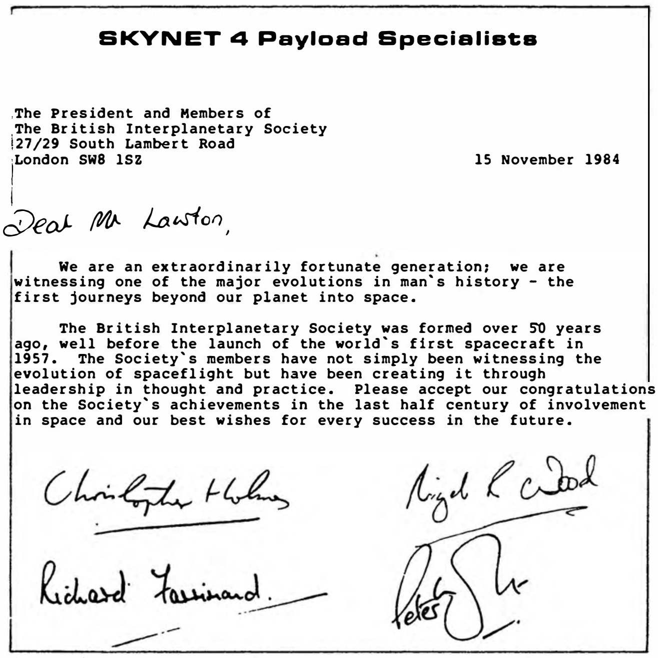
We even discussed for whose great-grandchildren, from among our acquaintances, we might hope to leave behind us invitations for seats on the inaugural service to Mars and beyond.

Coming to the present day, it is salutary to realise that this Conference, with its theme *The Future of Mankind* marks the entry of the Society into its second 50 years. To what realms will space flight have reached 50 years from now? One cannot help commenting that the big difference between our new explorations, looking into the 21st century (made possible thanks to people such as George Mueller, Bill McLaughlin, John Casani, Patrick Moore, and other distinguished toilers in the space arena here tonight) in these latter-day explorations we now know so much about those far distant places which we have yet to visit - whereas Columbus, Americo Vespuchi and Sebastian Cabot of earlier times set out, on even more hazardous journeys, with no knowledge at all of what was 'Beyond the Blue Horizon.'

So, clearly, a Conference such as this is immensely valuable in getting together such a distinguished and learned group of space scientists and engineers not only to look ahead at 'The Way to the Stars,' but also to seek an answer to that perennial question: "*Is* there intelligent life on *Earth?*"

All the more important, therefore, to set our sights on the broader visions of space. And I trust that the United Kingdom, and British Aerospace's Dynamics Group, will be empowered, and funded, increasingly, to contribute to vital space projects. As we know, at present the United Kingdom is spending only £80 million a year on space - which is not enough. Already Space Communications through Commercial Satellites is big business; and getting much bigger - with Ariane holding a backlog of launch-orders amounting now to more than £600 million.

Once again, may I say a most grateful 'thank you' for such an enjoyable evening among so many good friends, all with their eyes on the stars.



SKYNET 4 Payload Specialists

The President and Members of
The British Interplanetary Society
27/29 South Lambert Road
London SW8 1SZ

15 November 1984

Dear Mr Lawton,

We are an extraordinarily fortunate generation; we are witnessing one of the major evolutions in man's history - the first journeys beyond our planet into space.

The British Interplanetary Society was formed over 50 years ago, well before the launch of the world's first spacecraft in 1957. The Society's members have not simply been witnessing the evolution of spaceflight but have been creating it through leadership in thought and practice. Please accept our congratulations on the Society's achievements in the last half century of involvement in space and our best wishes for every success in the future.

Christopher Holmes   Nigel R Wood

Richard Farrimond   Peter

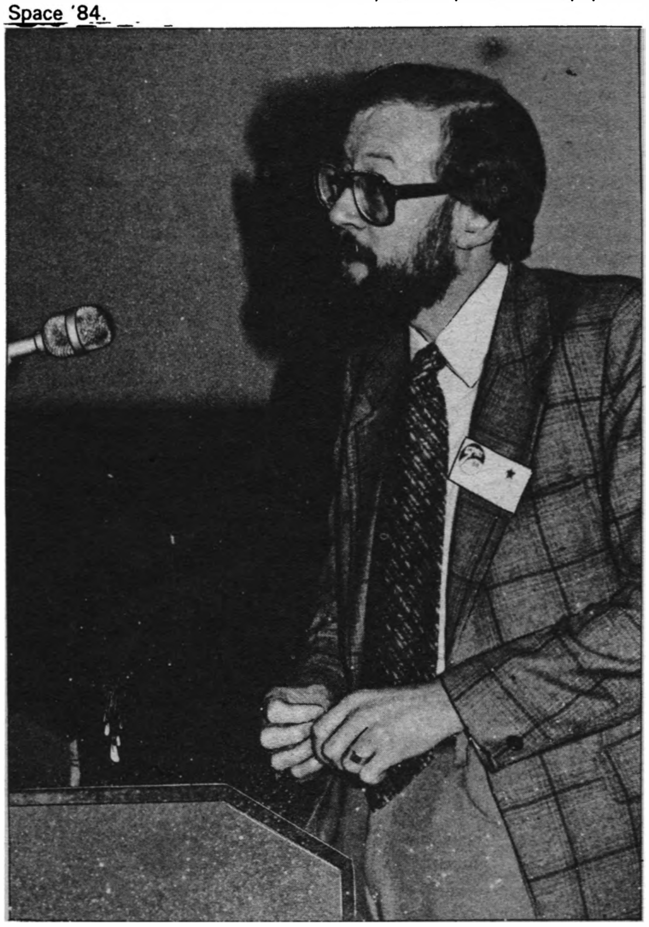
Space '84 was applauded by the British astronaut candidates Christopher Holmes, Richard Farrimond, Peter Longhurst and Nigel Wood.

form of instructions and reports.

No-one was ready for Patrick Moore, the second speaker who, spurning the microphone, let rip on an unsuspecting audience at machine-gun speed at the rate of about 20 anecdotes a minute. The audience simply rolled up at the plethora of Pat's recounted experiences, some of which defied belief but all of which, probably, were wholly true.

The third speaker, Sir Peter Masefield, Chairman of British Caledonian Airways, was thus left with the hard task of being a 'follow-on.' He rose to it gracefully. Sir Peter, as probably everyone knows, is a past-master of the spoken word. The audience was like putty in his hand. Not only was his speech salutory and informed but light-hearted and filled with 'digs' of every possible kind. The Banqueters rose as one man to applaud but, sadly, refused to leave afterwards, thus presenting yet again the problem of how to convert the Foyer Hall into its lecture plumage once more.

'Interstellar Studies' *JBIS* editor Dr. Tony Martin presents his paper at Space '84.



Ted Mallett of ESA begins the Banquet speeches.

Acknowledgements

Very many people contributed to the success of Space '84. We would like to acknowledge them all. Foremost are our speakers, our Guests of Honour, Dr. Wubbo Ockels, ESA Payload Specialist, Sir Peter Masefield, Dr. P. Moore, Mr E.S. Mallett and Dr. G. Mueller. Thanks are also due to Arthur C. Clarke, Dr. Gerry Griffin and the Crew of Shuttle 41G and to the four UK candidate astronauts.

We also acknowledge with thanks support from our exhibitors and to Douglas Arnold of Space Frontiers Ltd for his steady nerves, projection equipment, excellent photographs of the event and moral support at all times. To Wally Horwood of Western Glass International for the donation of cutglass decanters and other glassware to signpost the Society in fund raising and to all speakers for their excellent presentations, slides and hard work.

Our thanks are also due to Martin Postranecky, who acted as Press Officer and to the following members of the Society who rendered valuable help - Norman Nicoll, John Pearsall, Max Wholey, Claire Phillips and Ruth Shepherd and particularly to Eric Waine, who drove the van to and from Brighton and who suffered the consequences of the punctures on the way and to others who took photographs, with or without reimbursement, to help us record the event subsequently.

Finally, our thanks are also due to the Executive Secretary and his staff Ms. Lynda Lawford, Ms Susan Mandry, Ms Shirley Jones and Andrew Wilson, who also worried about the projection arrangements.

Finally, by way of tardy afterthought, we thank Martin Fry too who stepped into the shoes of our President at short notice and discharged his duties so well.

Space '86

Many of the interesting developments that will occur over the next two years will be featured in Space '86.

This will be held at the Brighton Centre once again. The dates will be 26-28 September 1986.

SPACE: THE FUTURE OF MANKIND

Theme Address

By Dr. George Mueller

The theme address for the Society's Space '84 conference in November 1984 was given by the distinguished speaker Dr. George Mueller. Widely recognised as 'The Father of Space Transportation,' Dr. Mueller addressed the BIS in 1968 when his talk 'Manned Space Flight: The Future' presented the first public disclosure of plans for the Space Shuttle.

At the time, Dr. Mueller was NASA's Associate Administrator in charge of the manned space programme. He directed both the Gemini and Apollo programmes that culminated in the first manned lunar landing in 1969. Before that, in 1965, he created the Apollo Application Program Office; this led to the launch of Skylab in 1973.

In 1967, he started the studies leading to an integrated plan for the next decade of space exploration, a plan built around the development of a low-cost, reusable Space Shuttle. This programme was adopted as official US policy in 1969 - the same year as the first lunar landing. Dr. Mueller is now President of the Jojoba Propagation Laboratories and the George E. Mueller Corporation.

Introduction

'Space: The Future of Mankind' is really a matter of philosophy rather than the ways and means of carrying out Man's future in space. Thus let me begin by quoting from a statement I made on 24 July 1969 on the occasion of the first manned lunar landing:

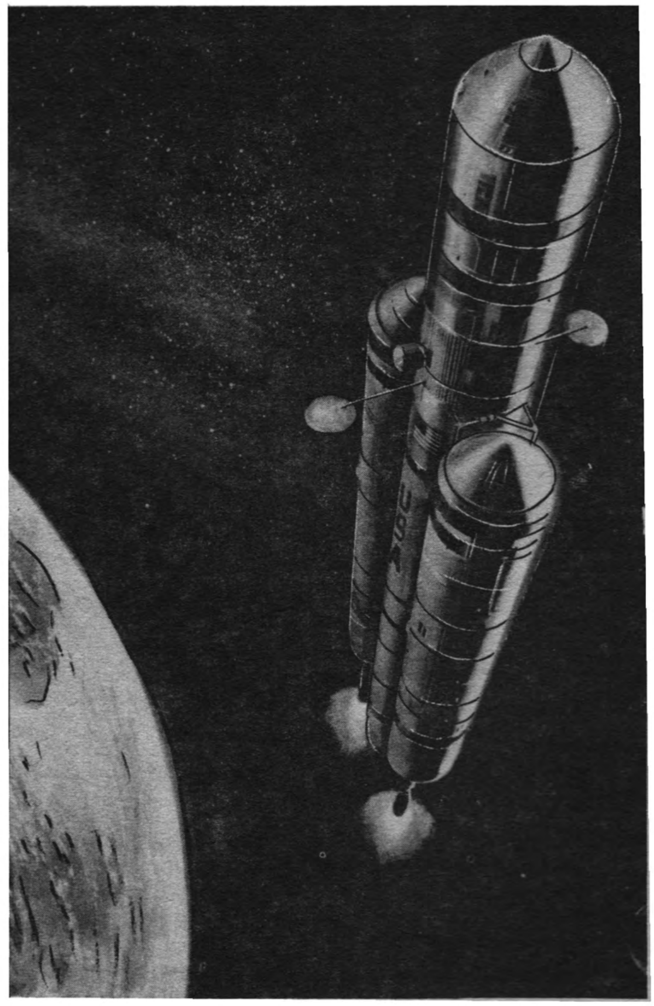
"Four billion years ago the Earth was formed. Four hundred million years ago life moved to the land. Four million years ago man appeared on the Earth. One hundred years ago the technology revolution that led to this day began. All of these events were important. Yet in none of them did Man make a conscious decision to follow a path that would change the future of all Mankind.

"We have that opportunity and that challenge today. There remains for Mankind the task of deciding the next step: will we press forward to explore the other planets, or will we deny the opportunities of the future?

"To me the choice is clear. We must take the next step. Should we hesitate to exploit the *first* step, should we withdraw in fear from the *next* step, should we substitute temporary material welfare for spiritual adventure and long-term accomplishment, then will Man fall back from his destiny, the mighty surge of his achievement will be lost and the confines of this planet will detroy him.

"This is a time for decision. This is a time for rededication to the spirit of our forefathers, a time for all Men to move forward together."

I think those words are as germane today as they were at the time of the Apollo triumph. I think that they are also true, for we find that our colleagues in the Soviet Union are working hard to develop the capability of carrying out all forms of space exploration. Clearly their emphasis on long-term duration in space stations can be of great importance in understanding the problems and the potentialities in visiting Mars, for example. The work that has now begun in the United States in the development of a Space Station will undoubtedly lead to a capability for orbital transfer which should form the basis for a consistent approach on the part of the United States to lunar exploration and, in the long term, to colonisation of the Moon and, eventually, to the colonisation of Mars. These are the first steps in what is clearly a long-term goal, a challenge and the destiny of Man.



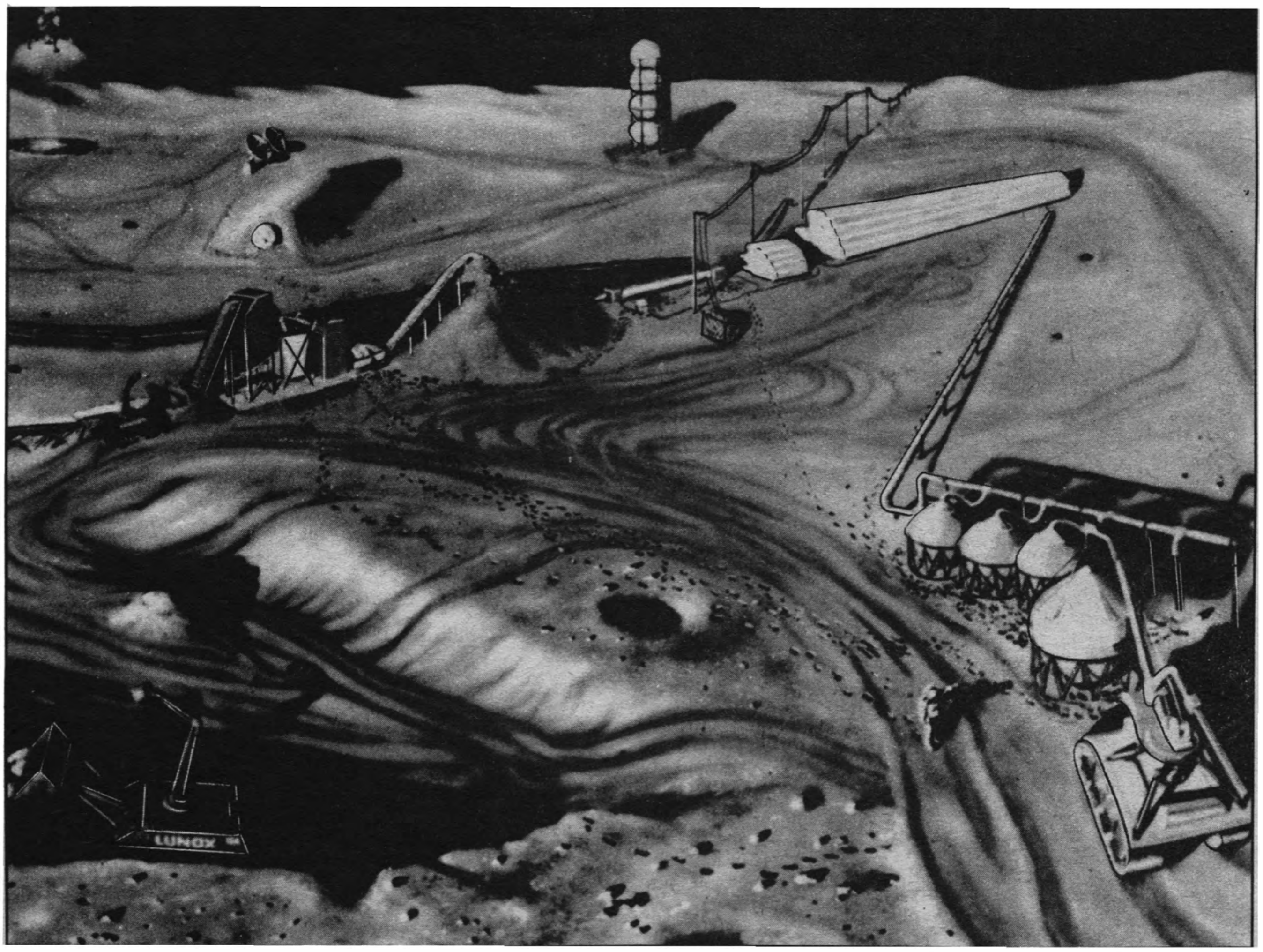
Although there are no firm plans at the present, Man will one day venture to Mars. This is a late-1960's concept produced by NASA for a manned expedition. *NASA*

The Reasons

My son has, from time to time, asked the questions what is the purpose of mankind? Why do we live here on Earth? And what are the expectations for the future for me and, by definition, for all men?' My daughters, who are somewhat older, went through a period of asking the same set of questions. These questions have occupied the minds and thoughts of philosophers since men first began to exercise the ability to think. That question is one that I have come to answer in my own mind, and hopefully for the understanding of my children, in the following way.

There must be a grand scheme for Man other than the confines of this small planet upon which we have been born and have grown to the position we now hold of dominance over all the species. It is clear that, if we are going to progress in terms of providing an expanding future for our children, we must provide for new frontiers, new places for us to develop our talents, our resources and our ability to sustain life, not only for ourselves but for all future generations.

So, my answer to that question is that the destiny of



Manned bases on the Moon, possibly for producing liquid oxygen propellant for space operations, will probably be established in the first decades of the next century.

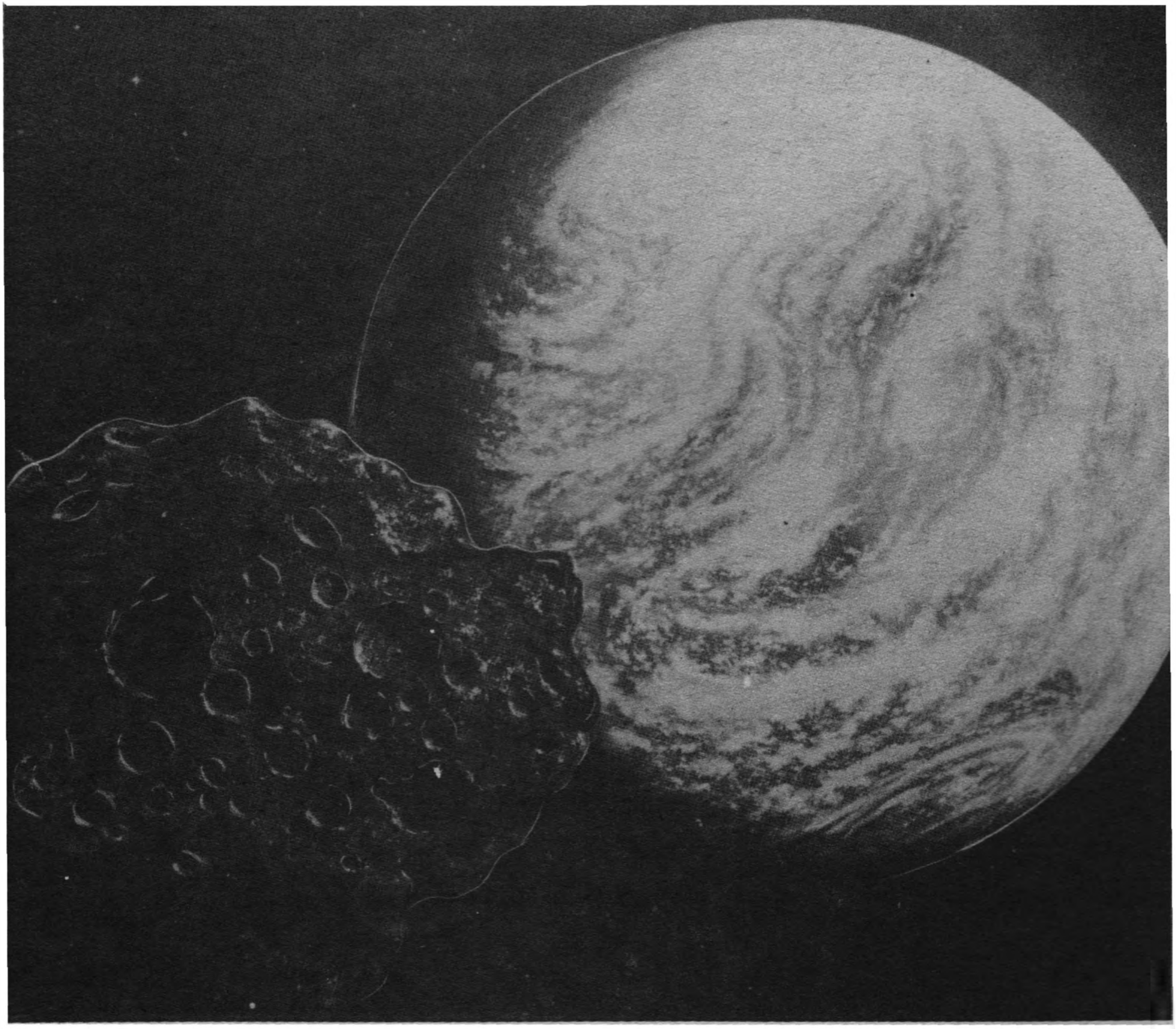
Mankind, the challenge to Mankind and the future of Mankind lies in populating first, the Solar System, from there developing the technology to visit the stars and to begin populating the Universe as we now know it. With such a grand design and such a profound challenge, we can occupy the excess energies of all men for the foreseeable future. Surely it is more fitting for the greatest race that has ever occupied this planet to cease destroying one another and sublimate that drive to propagating our species throughout the Solar System, thus providing the opportunity for future generations to spread to other stars and eventually to other galaxies. You ask yourself, 'is this too great a challenge?' and the answer is: "there has never been a challenge so great that, if Man was able to enunciate the challenge then he, in time, would meet that challenge."

There was a time when it was thought impossible for Man to fly on his own power alone. Yet we saw, just a year ago, that Man could fly under his own power across the English channel. We thought, at the beginning of the space programme, that Man could not exist in space for more than a few hours without having his body self-destruct. Yet we know now that there is essentially no limit to the time that men can exist in the weightless environment of space. Clearly the Russians have demonstrated their capability, in terms of the ability to live and function, to carry out a trip to Mars using even the crude equipment that we collectively have today.

If you were to ask me what the course of the development of Man's voyaging into space will be, I would say that we have already embarked on the first steps, and perhaps these first steps are the most important steps, because they have laid the groundwork of understanding that it is, in fact, possible to travel to other planets.

It is clear to me that we will want to establish colonies on the Moon and will need to exploit the resources we will find there, particularly as we take account of the need for the development of an infrastructure in space. The materials available to us on the Moon, resources in terms of solar power that are readily available there, and the lower gravity, provide for the basic needs of the material processing and transportation that are so important to the development of the cis-lunar space. In turn, that same development of technology and capabilities will permit us to develop the means for carrying out first the exploration, and then the colonisation of Mars.

As we look to Venus or, for that matter to Mars, one of the questions we have to face is that of 'do we modify these planets so that we can live there much as we do here on Earth?' Many years ago we made some calculations that showed that with a reasonable expenditure of funds, time and energy, we could provide a breathable atmosphere around the Moon. Such an atmosphere, once created, would sustain itself for a period of several hundred years. With what we know today, we may find it more expeditious to move one of the moons of Jupiter out of its orbit around that planet and into a collision course with Mars or Venus, in order to modify quickly the environments on those two planets. The one, to overcome the excess heavy gases in the Venus atmosphere, the other to provide larger amounts of gases and water in the atmosphere of Mars. We have an unlimited capability



Asteroids could one day be mined for their resources. This painting by BIS Fellow David Hardy shows an Apollo asteroid nearing Earth.
© D.A. Hardy

in that regard for modifying planets to meet the needs of life forms as we know them here on Earth.

Although this would probably be the least expensive in the long run, it is not necessary. One could build cities within bubbles that would sustain life and provide a relatively, perhaps even more, comfortable existence than we find here on Earth, since the atmosphere would be completely self-contained and controlled. Knowing men and their desire for freedom of motion, I think it is fairly clear that we will want to modify the planets as we begin to move from exploration into living on them, so as to make them the most comfortable for our forms of life. Inevitably, though, the question will arise as to what all of this will do for Man here on Earth. Why should this population support this adventure? I think it is important to note that the US space programme has brought about more than 12,000 products and techniques that did not exist just a decade ago. The investment in space has brought advances that would have taken centuries in the pre-1939 days.

In this connection, I read recently an interesting comparison of the physical world in which King Solomon lived to that of George Washington. Both wore homespun clothing; both used oil lamps for illumination; both heated with wood, and both travelled in horse-drawn vehicles. Both used the same primitive means of communication.

Since Washington's time we have developed new machine-made fabrics, synthetics, metals and even paper for clothing. We have seen the invention and efficient production and distribution of electricity, revolutionising illumination everywhere. We have seen the development of the use of coal, oil, gas, electricity and now nuclear and solar energy for heat.

The period of human development between King Solomon and Washington covered almost 3000 years, and between Washington and ourselves less than 170 years. But what a contrast in human progress!

Let us consider communication. Fundamental to all of Man's activities is his ability to communicate rapidly and with precision. One measure of our ability to communicate is the number of bits of information that can be transmitted per unit of time. Up through George Washington's day, communication was by means of signal fires, mirrors, drums, runners, pigeons, post riders and sentinels who relayed shouted messages. Today you can rent over £50 million worth of telephone equipment for a few small coins, while radio and television reach into every corner of the land. About 5,000 bits of information must be transmitted per second for intelligible voice communication, and some 10 million bits per second for high quality

television.

Or let us look at transportation. Up through Washington's time the top speed was about 50 km/hr - the speed of a very fast horse over a 1½ km distance. Over long distances, the fastest speed was about 16 km/hr, the pace maintained by the pony express riders in the 3000 km from St. Joseph, Missouri to Sacramento, California. Since that time we have witnessed the development of steam-driven locomotives and boats, vehicles using internal combustion engines, propeller-driven airplanes, jets, helicopters, air cushion vehicles, supersonic aircraft, nuclear propulsion and now rocket-propulsion aircraft and space flight. Today the top speed is 40,000 km/hr - the re-entry speed of a spacecraft returning from the Moon.

In Washington's time, human labour furnished a quarter and the labour of animals furnished half of all the energy required for life. At the present time every man, woman and child in the United States has more than 10 horsepower working for him 24 hours a day, and the figure is going higher every year. Had Man lived like this in the Periclean age of Greece, it would have taken the exhausting labour of 10,000 million human workers to provide the same benefits.

The Future

We will not have to wait another 170 years, however, to see the results of our present-day research and technology. The technological advances of today and tomorrow will influence our lives in ways unimagined as the dawn of the space age brightens into full day and this influence spreads, sometimes slowly, sometimes violently, into other areas.

In this regard I cannot help but be reminded of the bold and exciting and challenging programme that I outlined in a talk before The British Interplanetary Society in 1969. Here we laid the foundation for a far-ranging space programme that ended with a permanent colony on Mars as its goal for the end of the century. It is interesting that we have been following the steps outlined in that plan, *albeit* ever so slowly. We had anticipated having an operable Space Shuttle by 1976. We had exptected to have in orbit by 1980 a large, continuously-manned Space Station. That station would be made up of modules, each one of which could accommodate 12 people, and would serve as the prototype for the modules to be used for carrying out, first, the lunar expedition and eventually, as our knowledge increased, carrying out the Mars expedition. The Space Shuttle was the basic, first step in transportation, but envisaged at that time was an interorbital shuttle between low-Earth orbit and geosynchronous orbit, and between low-Earth orbit and lunar orbit. It is clear from all of our studies, borne out by the costs we are experiencing with the Space Shuttle, that one must minimise the expendables and utilise the same structure repeatedly if we are to reduce significantly the cost of transportation. So the whole space transportation system was based upon reusability. The Earth-to-orbit shuttle and return was fully reusable. The inter-orbital shuttle, powered by nuclear engines, was also completely reusable, and the lunar-orbit to lunar-surface (or Mars-orbit to Mars-surface) was again a reusable orbital vehicle re-supplied initially from the earlier staging points and eventually re-supplied from the infrastructures to be built up on the Moon and on Mars, as the case may be. The lunar colony we had expected to be able to have in place by the beginning of 1990, and the first trip to Mars we had expected to be possible by the year 2000. As I look back, that was a most ambitious programme. It was also a programme that was completely possible, providing the necessary resources had been dedicated to carrying it out. You may say 'well, that would be an excessive diversion of resources' and yet all of our estimates indicated that we could carry out this programme with no greater funding annually than that which we had had for the Apollo programme. Incidentally, that funding is not very far off the amount that the Soviet Union is now spending on its space programme, some three times greater than US expenditure.

The evolution of our race has been punctuated by the attainment of new environmental freedoms. It took 4000 million years for life to venture on to the land. As the result of this new environment, 400 million years ago Man first appeared on Earth. Only 4000 years ago Man developed his first real transportation system - the sailing ship - and with this as an aid he has populated the world Today we have taken another great step in entering into a new environment. We now have a transportation system that will take Men to the planets. Soon our life forms will exist throughout the Solar System.

Attraction to the mysterious and unattainable has always been our deepest and most basic motivation. And properly so, for only through our understanding of natural forces and our ability to adapt them to our needs have we improved our earthly condition.

I believe that Men are going to live and work in space and are going to explore and colonise the Moon. Our never-satisfied curiosity will drive us to the limits of our intelligence, our adaptability and ingenuity.

As we move out into the Solar System we will be looking for other forms of life but I believe that our greatest contribution will be the establishment of our own life forms on the arid worlds of our Sun. As we build this new civilisation and become citizens of the Solar System I believe we will be building a better life for all men and, at the same time, building the capability required for men to go to the stars.

But as we do this we will be confronted not only with technological change and the accompanying material changes, but also with social changes and even spiritual changes. Following in the wake of these will come problems of adjusting to new ways of life. Human beings often resist change, clinging tenaciously to entrenched attitudes and habits - expecially if adults. Sometimes we seem confused, frustrated, and even angered by an advance that upsets our normal routine or outlook. In fact, some of our adults are still being dragged, kicking and screaming, into the space age.

All of this presents an exciting prospect. Because of the instruments of exploration now available to us, along with the quest for scientific discovery and the power of historical force, we may be on the verge of the greatest 'revolution' of all time: a revolution in human affairs.

One of the major forces of this revolution will be our probe into space. The impact of space exploration will extend far beyond science and technology. Its effects will be felt, and applied, in every area of human activity and thought.

If I may, let me hark back to the words of one of the great people in my life. Perhaps the simplest, most eloquent reason for exploring space was expressed by the late Dr. Hugh L. Dryden, the distinguished first Deputy Administrator of NASA, and Home Secretary of The National Academy of Sciences, when he said:

'None of us knows what the final destiny of Man may be - or if there is any end to his capacity for growth and adaption. Wherever this adventure leads us, we in the United States are convinced that the power to leave the Earth - to travel where we will in space - and to return at will - marks the opening of a brilliant new stage in Man's evolution.'

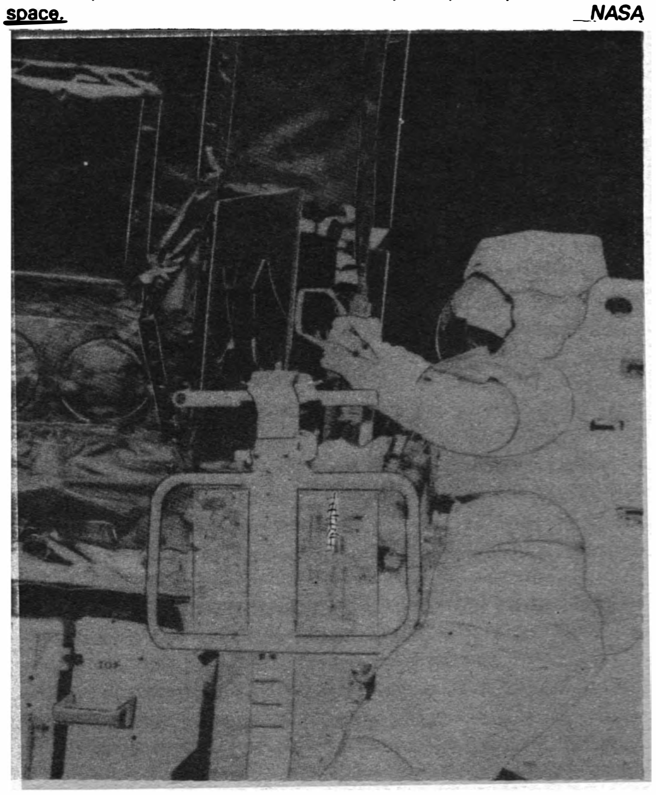
Man: Cosmic or Cocooned?

Sir, An essential area of misunderstanding is the purile e.g. robotics *v* human astronauts debate. Opposition tends to stem from those in some universities, already subject to budget restraints, who see manned space flight as something which would drain away some of the funds they want. They do not yet appreciate the American experience where the scientific fraternity discovered that, far from doing any such thing, projects of the magnitude of the sort envisaged are far more likely to provide the scientist with a new lease of life and added incentives to investigate completely new areas. Instead of their opportunities folding up, American scientists are finding new vistas emerging, with expanding opportunity for the younger scientists to undertake new and original research and to make their mark in completely new ground. The simple existence of the American University Research Program and the enormous participation by universities throughout the States bears eloquent testimony to this and the fact that such universities, by virtue of such involvement, become more intimately involved in the lifeblood of the country, instead of remaining on a purely intellectual plane.

So the current manned *v* unmanned roles in space argues the wrong question. It is obvious that there must be a proper mix. Astronauts must be used in the most productive and creative way.

For a good mix we can take the example of the Space Station - with unmanned platforms undisturbed by astronauts though with the capacity for humans to move across to tend and repair them as required and thus ensure their continuing usefulness. The SMM mission was a classic example of how valuable such a role can be. Machines must be used to best advantage, too. This is where the challenge of the right mix comes in.

The repair of the Solar Max satellite in orbit during Shuttle mission 41C in April 1984 demonstrated the unique capability of humans in space. *NASA*



Another example was the first Spacelab, multi-disciplinary and probably the most difficult of all the Spacelab flights - with astronomers looking up, remote sensing scientists looking down and the material scientists in between requesting that nothing be moved or disturbed. Even so, the flight was so successful that, if anything, there weren't enough people up there to move things around. Future flights are more likely to be single disciplines.

A suitable role for ESA might be to provide a full and complete laboratory module - solely ESA constructed and operated in conjunction with the NASA Space Station - with NASA simply providing the interface. This might meet the need for a major contribution, not just an add-on.

Users would probably come in three categories:

1. Scientific and applications would include remote sensing.
2. Commercial users. Only pharmaceuticals have been identified so far but many others could, potentially, exist.
3. Technology development missions.
4. Overlaying all special domestic i.e. national projects applicable to one country as well as those appealing to a group i.e. marking a particular area of joint study.

Who wears the blinkers, the scientist endeavouring to jam us into this world forever, or those seeking a foothold (note the use of the word) in space?

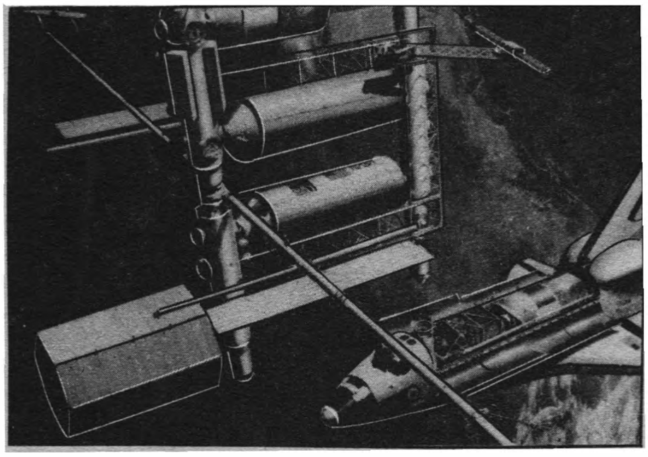
P.R. FRESHWATER
Oxon

The Space Station: a 'Science' Viewpoint

Sir, There are many reasons why nations become involved in space: politics, adventure, technological catalyst, commercial exploitation, military, scientific research, etc. Scientific research alone could never have attracted the enormous investment into space over the past quarter century. *Nevertheless,* scientific research and the development of new technology demanded by the scientists had preceded almost all other uses of space. Science has shown itself to be at the 'hyper-technology'/'risk' end of the business. Commercial exploitation, for example, demands space-proven technology. UK aerospace companies have acknowledged that the national scientific satellites were the 'seedbeds' of the UK satellite industry; the UK got into commercial space projects *via* scientific space projects. Science *should* have a future role as catalyst to the UK space industry. Indeed science might even be seen as providing a service to the rest of the space community by helping to push forward the frontiers of space technology.

In the US, space science is now recognised as perhaps the ultimate justification for the Space Station. The requirements of science must, therefore, be at the forefront of Space Station planning in Europe, as they are in US.

Space scientists, had they been sole masters of their own destiny, would not yet have chosen Space Station as the highest priority requirement for the future of space research. However, since the Space Station is definitely going to happen, scientists will certainly want to make good use of it and wish to influence its design, development and deployment. 'Space' will not be the same in



the 1990's, with the advent of Space Station, so scientists need to get used to that fact now. Scientists might have to face the choice 'Join in the Space Station, or drop out of space research.'

Proposals for scientific utilisation of Space Station include:

Astrophysics
1. Large cryogenically-cooled telescope (for infrared astronomy, and Earth observation).
2. Large radio antenna (for Earth observation radar plus radio astronomy).
3. Broad-band Space Telescope: 4 m class (from far ultraviolet to near infrared, interferometric arrays).
4. Advanced Solar Observatory.
5. Large gamma-ray and cosmic-ray detectors.
6. X-ray Telescopes - High Throughput Spectrometers.

Geophysics (strong SERC-supported community)
1. Large cryogenic systems.
2. Incoherent scatter radar, for ionospheric research.
3. Versatile large, high power atmospheric sounding radars.
4. Synthetic Aperture Radars.
5. Radar altimeters.
6. High-power LIDAR.

Microgravity Physics and Chemistry (negligible UK involvement to date).

Enabling Technology (SERC interest; modest programme to date).

It is recognised that certain large payloads might be built more cheaply if launched in unassembled configuration. Space Science must become more cost effective if instruments can be matched to a common in-orbit 'bus,' with added potential of in-orbit repair and reconfiguration.

The following list represents the *minimum* requirements identified by space scientists (of course, many of these are already part of the Initial Operational Capability):

1. Polar platforms (Sun synchronous, dawn-dusk plus day-night) as well as 28° orbital station.
2. Small free flying (single instrument) platform capability (for pointing stability; contamination free environment; novel orbits, etc).
3. Ease of in-orbit assembly and refurbishment of instruments; shirt-sleeve environment (hangar module).
4. Access *to* and *from* geostationary and highly-eccentric orbits (Orbital Transfer Vehicle).
5. Extreme pointing stability for astronomical payloads.
6. Improved data links; NASA's TDRSS satellites will not suffice. (Investigate alternative of on-board 'pre-processing' and data compression).
7. Observers on-board, for certain payloads.
8. Investigate more cost-effective 'trucking' system than Shuttle.
9. Freedom must be retained for small, Explorer-class satellites.
10. Environment of Space Station must be controlled at least to the cleanliness level established for Shuttle.
11. If Space Station is to be fully exploited scientifically, money for space science must be protected.

Ideas from UK scientists about how UK/ESA might become involved include:

1. The UK should invest in new technology areas and not just seek short-term commercial return based on existing technology. Hyper-technology areas the UK might get involved in include:
   - robotics: in-orbit assembly and refurbishment technology
   - artificial intelligence
   - predictive vision
   - novel structures, materials, optical systems, etc.
   - precision pointing systems (star trackers, gyro control), etc.
2. The UK might consider providing a major *facility*, for example:
   - free-flying (single instrument) platforms
   - cryostat, for Earth observation and astrophysics
   - advanced bio-rack
   - large format high-resolution detectors
   - large antennae (for radars, microwave radiometry and radio astronomy)
   - Data Acquisition Centre
3. The UK should seek to diversify its investment in Space Station
   - station/platform hardware
   - scientific facility
   - data/communications segment
   - software (artificial intelligence, etc)

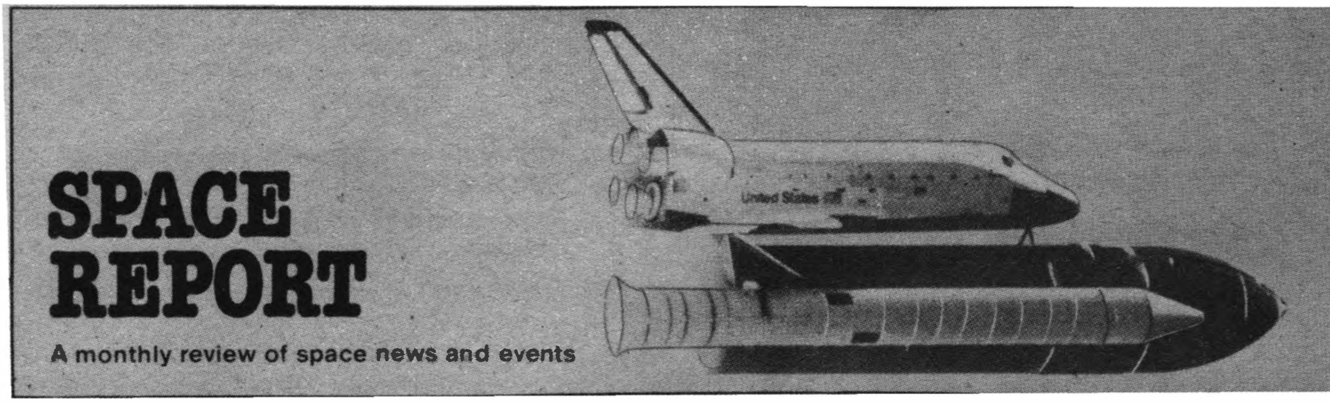
Dr. D.H. CLARK
Rutherford Appleton Laboratory
Oxfordshire

Astronomical Satellite

Sir, Contrary to the NASA statement concerning the Extreme Ultraviolet Explorer (EUVE) reported in *Spaceflight* (December 1984, p.444), the British Wide Field camera on board the German ROSAT spacecraft will perform the first all sky survey in the extreme ultraviolet band. ROSAT is scheduled for launch in 1987.

JULIAN DANIELS
University of Leicester

The Editor is always interested in receiving items of correspondence, notes, comments, or similar material for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine. The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.



SPACE SHUTTLE

EXTRA SPACELAB FLIGHT?

British Euro MP Robert Battersby (Conservative-Humberside) is pressing the European Commission to sponsor a further flight of the European Spacelab aboard the Shuttle. Mr. Battersby tabled a Motion for a Resolution calling on the Commission to 'provide, as a matter of urgency, effective support to potential industrial users to enable them to participate in a Community sponsored Spacelab facility utilisation programme which will enable them to gain vital experience in this field.'

Mr. Battersby said, 'The 71 experiments conducted aboard Spacelab during the STS-9/SL-1 mission are producing some exciting results. However, there is still considerable scope for Europe to develop further its expertise in such areas as material processing in Space Station microgravity environments, bio-pharmacy and semiconductor manufacture.' Mr. Battersby is concerned that Europe could lag behind in the development of high technology. In a written question to the European Commission, he asked it to recognise the 'prime importance for the commercial future of Europe in space,' and called on the Commission to take 'priority action.'

Mr. Battersby points out that ESA, as well as Community Member States, are carefully considering the rôle that Europe will take in space stations with the knowledge that the commercial opportunities are great. He said, 'Independence by Europe, of the USA and USSR, in manned space flight by the turn of the century is a realistic goal. Excellent work has been done by ESA and its contractors in developing Spacelab as a tethered space station in the Shuttle, which has already demonstrated Europe's capability. However, the considerable funds already expanded by EEC Member States on participation in the Spacelab project have so far produced only limited benefits. Stimulation of user awareness and involvement is the key to the future success of community investment in this field. To this end, another European-sponsored flight of Spacelab will be vital for our future participation in, and utilisation of, space technology.'

INDIAN LAUNCH AGREEMENT

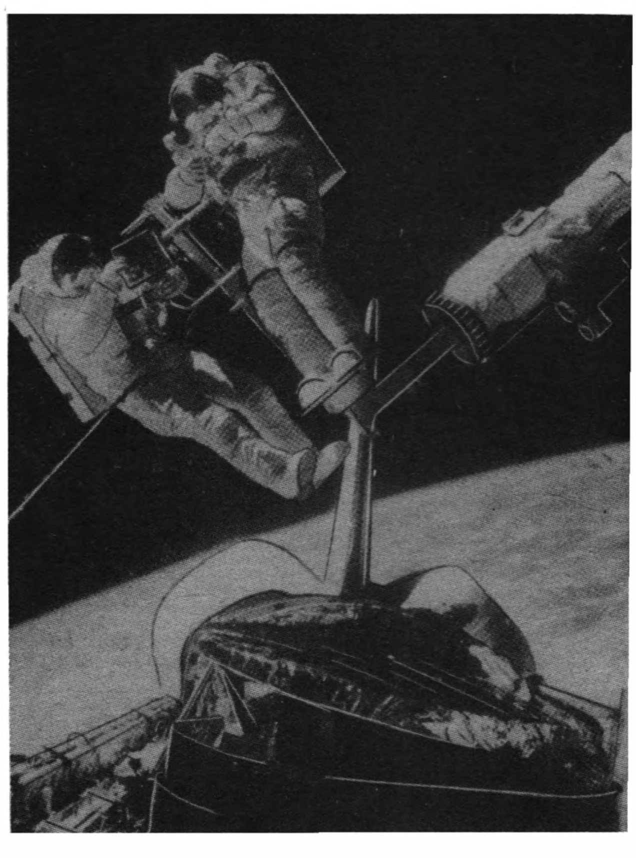
NASA Administrator James Beggs and U.R. Rao, Chairman of the Indian Space Research Organization, have signed a launch services agreement covering the reimbursable launch of the Indian National Satellite, Insat 1C, scheduled for mid-1986 aboard the Shuttle. It is a multipurpose satellite that will provide communications and meteorological services to India. An ISRO scientist/engineer will serve as a payload specialist aboard the Shuttle during the mission.

In addition, discussions were held on experiments that the Indian payload specialist could perform, and potential coöperation between NASA and ISRO in space applications and space science.

SATELLITE FOR SALE

When Telesat Canada ordered the Anik C1 communications satellite several years ago, market predictions indicated that there would be a need for the satellite's high frequency transponders to relay telephone and educational TV traffic across Canada, writes Joel Powell. However, Telesat is now faced with launching a satellite that will not be used because there is no longer a demand for its services. Telesat intends to avoid the costs of

This photograph sums up the success of the Shuttle 51A mission last November when astronauts Allen and Gardner recaptured the Palapa and Westar communications satellites (seen at bottom). Here, they hold up a sign saying 'For Sale.' *NASA*



maintaining it in on-orbit storage. Anik D2 has also been placed in on-orbit storage (for two years) following launch from Shuttle 51A last November because demand for its services has also lagged behind the projections.

SATELLITES

EURECA APPROVED

After a three-year study effort, ESA will proceed with the development of Europe's first retrievable carrier, Eureca. It is not only a logical follow-on to ESA's Spacelab programme, it is also a first step in a future European long-term programme of space transportation systems, providing experience in the development of unmanned automated platforms.

Eureca will be first launched from the Space Shuttle in early 1988. After deployment by the Orbiter, the platform's own propulsion system will take it into an operational orbit with an inclination of 18.5°, some 500 km high. Its large solar arrays will then be deployed and its thermal/cooling and data systems switched on and tested. Finally, the payload will be switched on and operated by remote control from an ESA ground station under the responsibility of the European Space Operations Centre. It will operate as a free-flyer for six months before returning under its own power to meet the Shuttle in a 296 km orbit. The Orbiter's remote manipulator arm will retrieve the platform and place it in the cargo bay, ready for return to Earth. It will then be transported from the US back to its home base, Europe, for refurbishment prior to its next mission.

This first Eureca payload consists mainly of a 'core payload,' making up about 66% of the total 1000 kg payload mass available. The core, developed and funded by ESA, consists of five facilities designed specifically for experiments in the microgravity environment (materials and life sciences).

Another important aspect of the first mission is the inclusion of an Inter-Orbit Communications (IOC) package for a data transmission experiment, forerunner of a future European Data Relay System. This experiment will consist of establishing a data link between Eureca and the ground using the 20/30 GHz payload on-board ESA's Olympus communications spacecraft in geostationary orbit. IOC definition studies have been executed under ESA's future Telecommunications Preparatory Programme and should be completed by the end of April.

The rest of the payload includes two additional microgravity facilities (one German and one Italian), together with a number of space science and technological experiments. The total cost for the whole of the programme amounts to 206 million Accounting Units at mid-1983 price levels (approximately $165 million). Of this, 116.5 MAU has been earmarked for the industrial development (phase C/D); an additional 25.5 MAU has been reserved for the development of the core payload.

ION CLOUD RELEASES

A cloud of barium atoms, released at an altitude of 125,000 km on 27 December 1984 high above the Pacific, formed an artificial comet as the solar wind drove the plasma away from the Sun. Two earlier releases of ions by the Ampte satellite trio (lithium in both cases, and both ahead of the magnetospheric bow shock wave, in September 1984) were successful. It has been deduced from measurements made by the two satellites in the vicinity that both events produced enormous clouds of plasma with comet tails streaming away from the Sun before being deflected by the protective screen of the geomagnetic field. The plasmas were extremely tenuous - less than 1 kg of material produced 30,000 km diameter

An artist's impression of Eureca in orbit. *ESA*

clouds. Towards the end of 1984, however, the Earth's motion had brought the high points of the spacecraft's orbits to the side of the Earth-Sun line, in the magneto-flank, where a carefully planned barium release was detectable by instruments on board the German Ion Release Module, the United Kingdom Spacecraft and the American Charge Composition Explorer.

Both earlier releases have given the Ampte scientists new information about a collosal and fascinating region of Earth's near environment. This event and further releases in the spring will continue to show scientists how to fill the gaps in our understanding of plasma interactions and of ion and electron acceleration in the magnetosphere.

BRITISH CHINESE DBS LINK

British Aerospace is working with the French aerospace contractor Matra on the design of a direct broadcast satellite for the People's Republic of China. That nation has been interested in direct satellite broadcasting of TV and sound signals since before 1977 when their requirement was registered with the International Telecommunications Union. In responding to the request from China, Matra and BAe are confident that the design, which will incorporate the latest technology in both spacecraft and payload, will satisfy all the requirements issued by the Chinese Government.

The proposed satellite will also meet the full requirements of the international satellite broadcast plan and use shaped beam antennae to concentrate the signals and minimise the overspill into adjacent geographical areas.

STATION MODULE STUDY

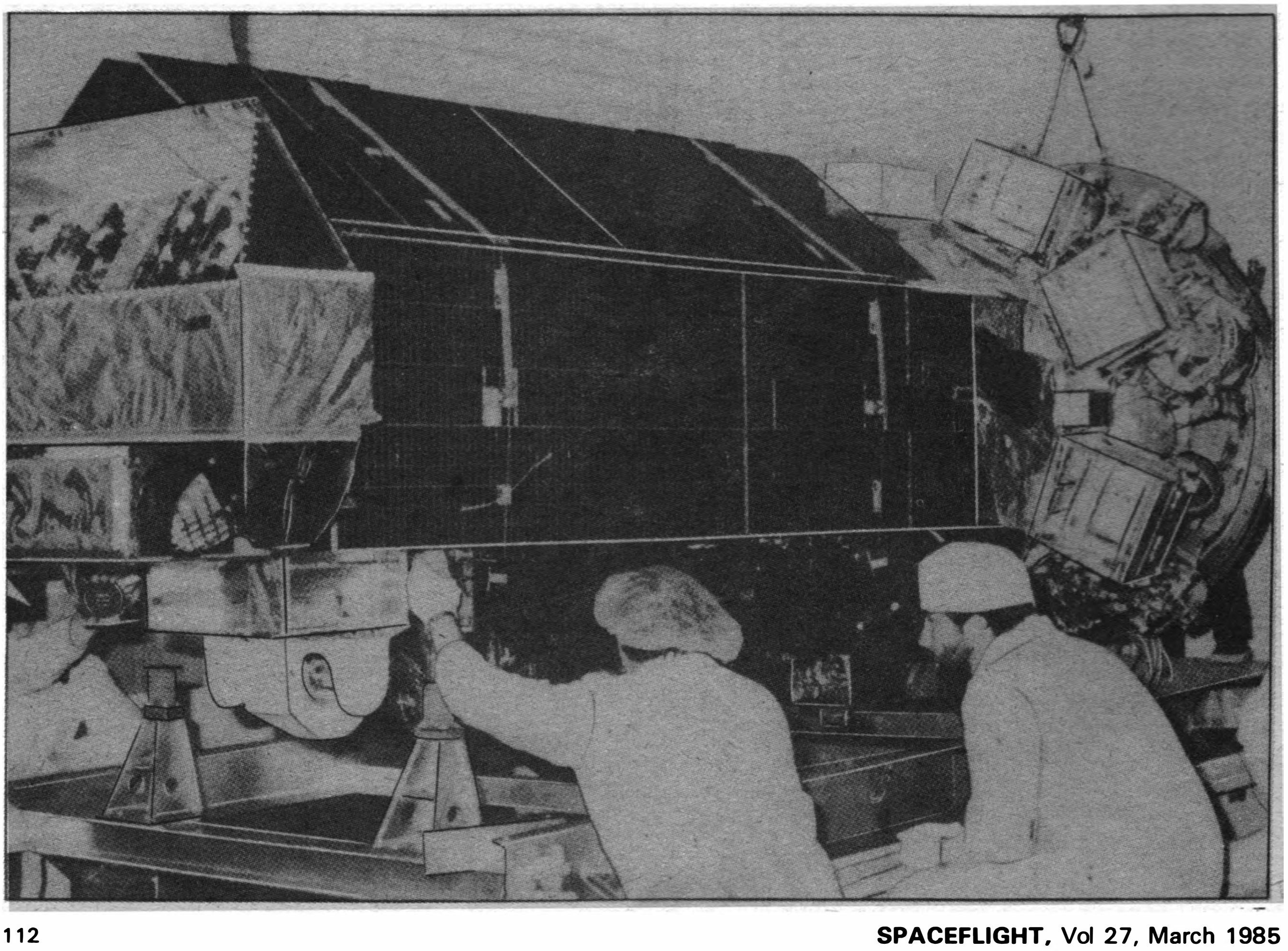
A $2 million contract to study aspects of an orbiting research facility was awarded last November by NASA's Marshall Space Flight Center to Teledyne Brown Engineering. The two-year contract is for a basic conceptual study of equipment and other aspects of a pressurised microgravity materials sciences laboratory module. The award of the design study of the overall module itself was expected early this year.

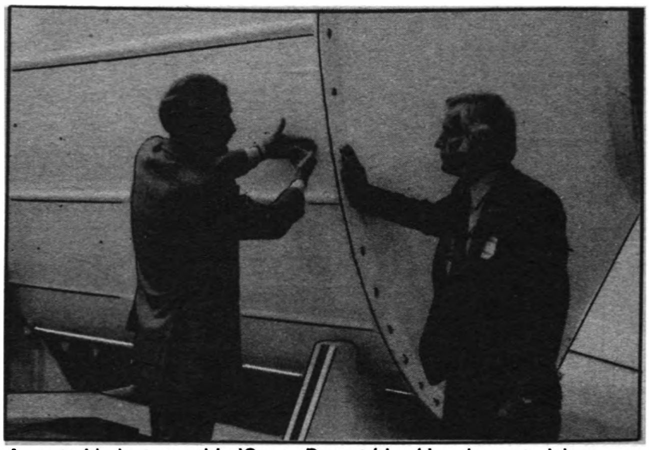
The Marshall Center is charged with management of the design of a 'common' module, several of which would be used for the Space Station. This common module, with variations, would be designed for living quarters for the station crew, for laboratory research and commercial manufacturing, and for logistics: the storing of replenshable goods used by the crew, such as water, food, clothing and oxygen.

The study is concentrating upon the requirements that scientific research and commercial manufacturing will impose on the common module. The contract calls for the company to identify specific equipment and hardware that would go into the module, identify potential commercial research and development activities in which the module could be used and establish operational requirements for the government, academic institutions and industry.

This laboratory module, called a Microgravity Materials Processing Facility, would provide a shirt-sleeve environment for those working inside it. Among the diverse

The NOAA 9 meteorological satellite was launched last December to provide environmental data. It is also equipped with search and rescue instruments to continue the SARSAT/COSPAS international rescue system. *RCA*





As noted in last month's 'Space Report,' Lockheed are studying ways of improving crew performance aboard the US Space Station. The picture shows Tom Fisher, manager of Crew Systems for Lockheed, with ex-astronaut Deke Slayton, who is serving as a consultant, with a full-scale mockup of a 'habitability' module.

scientific areas in which technicians would be working are materials processing, which could involve crystal growth studies and the formation of new alloys; biotechnology; physics and chemistry applications; and combustion sciences.

The Marshall Center expects to award contracts for definition study of the common module by this spring. These definition, or 'Phase B,' studies will examine in closer detail the module designs that will ultimately be built and flown.

ARIANE LAUNCH SCHEDULE

The latest launch list for Europe's expendable Ariane satellite launcher shows a flight rate of at least half a dozen per year, made possible by the introduction of a second launch pad at Kourou with flight 15 in August. Most of the payloads are communications satellites: STBS (Brazil), Arabsat (Arab League), Gstar and Spacenet (GTE Spacenet), Telecom (France), ECS (Europe), Intelsat (Intelsat), Aussat (Australia), Tele-X (Sweden), Olympus (ESA), TV-Sat (W. Germany), TDF (France) and SBS (US commercial). Spot is the French remote sensing satellite and Viking is the Swedish scientific craft.

Launch	Flt.	Type	Payload
1985			
Feb	12	3	STBS 1 + Arabsat
Apl	13	3	Gstar 1B + Telecom 1B
Jly	14	1	Giotto
Aug	15	3	Spacenet 3 + (STBS 2 or ECS 3)
Sep	16	2	Intelsat 5 F13 or Spot + Viking
Nov	17	1	Spot + Viking or Intelsat 5 F13
Dec	18	3	Gstar 1A + (SBTS 2 or ECS 3)
1986			
Jan/Feb	19	2	Intelsat 5 F14
Apl	20	2	Intelsat 5 F15 or TV-Sat
May	21	2	TV-Sat or Intelsat 5 F15
Jun	22	3	Aussat 3 + free
Jly	23	4/2	Ar. 4 test, or Ar. 2 with TDF-1
Aug/Sep	24	2/4	TDF-1 or Ar. 4 Test
Nov	25	3	SBS 5 + free
1987			
Feb	26	2	Tele-X
Apl	27	4	Free
Jly	28	3	Olympus 1

MILESTONES

November 1984

29 Miss Baker, the tiny squirrel monkey that rode into space inside a Jupiter missile nosecone in May 1959, dies at Auburn University, Alabama following kidney failure.

30 The Palapa and Westar satellites, rescued by Shuttle 51A, are flown to the manufacturers for examination.

December 1984

3 The Soviets are preparing their shuttle orbiter for air-drop tests, it is reported.

3 The Instrument Pointing System for Spacelab, which will point telescopes very accurately (0.8 arcsec) has been delivered to NASA by Dornier from W. Germany.

5 The NOAA 7 weather satellite is sent tumbling by an incorrect command; it takes 40 hr to bring back under control.

6 The bulk carrier *Ocean Aspiration* is equipped with the 3000th ship Earth station of the Inmarsat maritime satellite communications system.

11 Krafft Ehricke, V2 engineer and space pioneer, dies at the age of 67.

12 The NOAA 9 weather satellite is successfully launched into polar orbit by an Atlas from Vandenberg Air Force Base. (The '2' was omitted from the launch date given in February's 'Space Report.')

14 The European Space Agency announces that it will proceed with the development of the Eureca retrievable payload carrier, due for first launch in 1988 from the Shuttle.

14 The Venera 15 and 16 Venus radar mappers have discovered several hot spots on the planet that might be active volcanoes. Other features appear to be inactive volcanoes.

15 The Soviet Vega 1 Venus/Comet Halley probe is launched. It is due to release a landing capsule and balloon probe at Venus next June and intercept the comet on 6 March 1986. Vega 2 is launched on the 21st.

18 NASA and India sign an agreement to launch the Insat 1C satellite aboard the Shuttle in 1986, as well as provide an Indian payload specialist.

19 Salyut 7 has now been operating for 32 months. It has now completed 15,400 orbits and is presently in a 366 x 387 km, 51.6° orbit.

19 Cosmos 1614, another small Soviet shuttle test model, is launched and successfully recovered in the Black Sea.

21 The Soviet Vega 2 Venus/Halley probe is launched. It is due to encounter the comet on 9 March 1986.

21 The 16th anniversary of the launch of Apollo 8 with astronauts Frank Borman, Jim Lovell and Bill Anders.

27 The Ampte satellites produce and study an artificial comet by releasing barium atoms 125,000 km above the Earth.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

FUTURE SPACE TRANSPORTATION

By M.W. Jack Bell

The author describes the basic requirements for the vehicles that will follow on from today's Space Shuttle; the full-length paper appears in December 1984's 'Space Technology' issue of *JBIS*.

Introduction

As Space Shuttle operations approach maturity at the Kennedy Space Center in Florida, studies are being made by various US contractors of the options for the next generation of space transportation systems. Studies recently conducted at Rockwell's Space Transportation System division have concluded that advanced technology will be required to provide a substantial improvement in operational economy over the current Shuttle. The most important, and probably the most difficult to develop, advancement is very high strength and stiffness-to-weight ratio structures. The next most important are much higher reliability and greatly extended lifetimes for components.

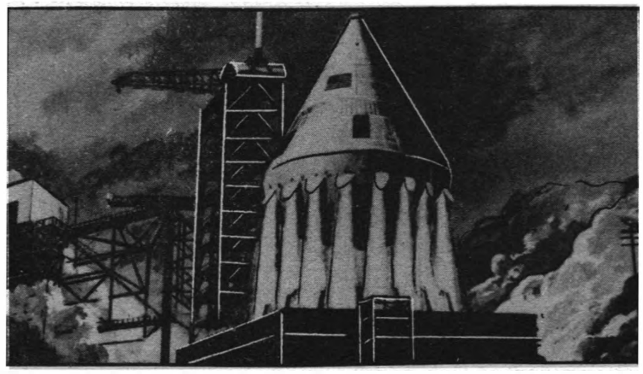
Lightweight structures are necessary to achieve fully reuseable single-stage-to-orbit vehicles to avoid the cost associated with expendable hardware and multi-stage system integration and turnaround costs.

Several materials are being evaluated now that might produce the required properties. Metal matrix materials, including aluminium alloy matrix with randomly-oriented embedded silicon carbide whiskers, is one possibility; another is aluminium or magnesium alloy matrix with similar graphite whiskers. Much work remains to be done before it would be wise to use them in space flight.

Design Constraints

High reliability and long life of equipment is necessary to assure operational availability of future vehicles with minimum manpower devoted to operations support.

It is not possible to define the next generation until the



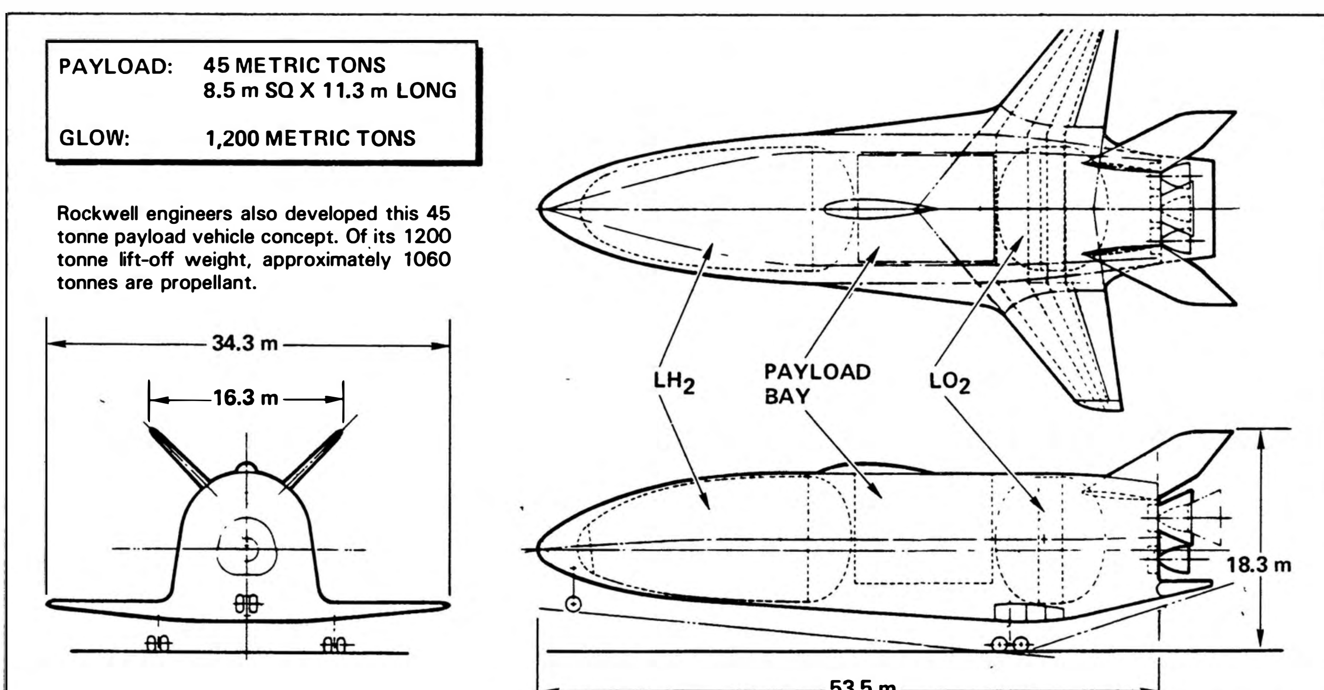
This vertical take-off, vertical landing concept was sized by Rockwell engineers to deliver 150 tonnes to a low altitude Earth polar orbit. It has a lift-off weight of over 4500 tonnes with propellant accounting for 90%. It would re-enter in a manner similar to the Apollo command module.

applications and mission requirements are established. Obviously the mass and volume requirements of the payload must be established, as well as understanding of return payload requirements. Delivery orbit altitudes and inclinations and flight frequency requirements must be projected.

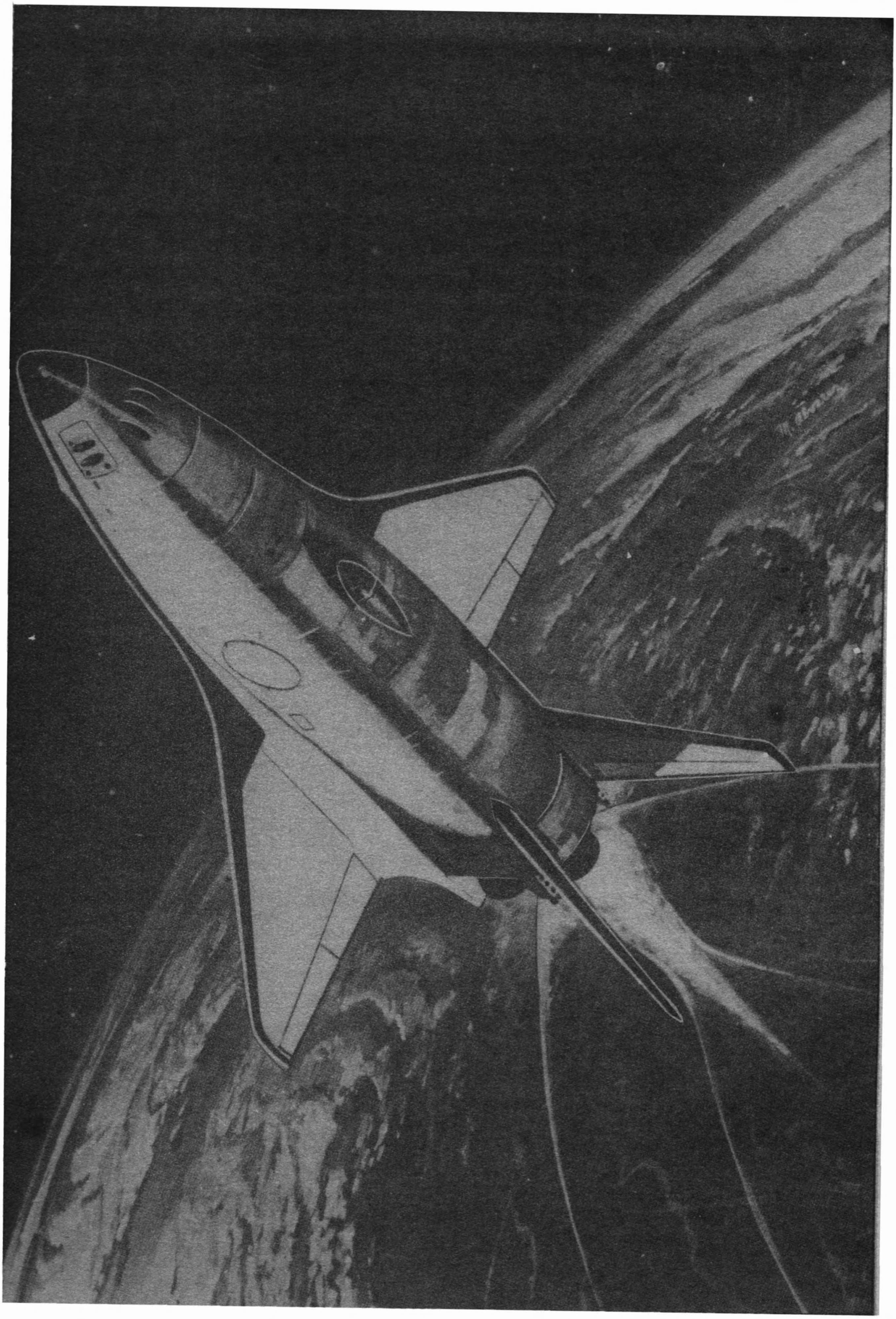
Until these parameters are defined, space vehicle system conceptual designers can only guess at what type of system will be developed next.

In lieu of defined system requirements, engineers at Rockwell have considered a spectrum of future systems from small to very large and massive payloads. Vertical take-off, horizontal landing configurations have been synthesised for low Earth orbit systems with payload weights varying from 2.5 to 70 tonnes. Aircraft-like configurations appear to be possible for delivering payloads of up to about 70 tonnes. Above this, lifting surface and landing system requirements become very difficult to accommodate on a single-stage-to-orbit aircraft-like configuration. At some point a vertically landed low lift-to-drag ratio configuration appears to be a better option.

Right: This 7 to 18 tonne payload vertical take-off, horizontal landing second generation space transportation system configuration concept was developed by Rockwell. Lift-off weight is about 700 tonnes, of which 88% is liquid oxygen and liquid hydrogen propellants. The payload capacity depends greatly on the vehicle's empty weight.



Rockwell engineers also developed this 45 tonne payload vehicle concept. Of its 1200 tonne lift-off weight, approximately 1060 tonnes are propellant.



JAPANESE SPACE SCIENCE

By Neil W. Davis

Introduction

With the launch of their first heliocentric orbit probe, MS-T5, Japanese space scientists are entering a new era. Japanese space science is celebrating its 30th anniversary; in early 1955 the University of Tokyo's Institute of Industrial Science embarked on a programme to develop sounding rockets for upper atmosphere research for the International Geophysical year of 1957-58. Twenty years ago, in 1965, the National Space Activities Council (predecessor to the present Space Activities Commission) announced the go-ahead for the planning stages of a 'Scientific Satellite Program' that was proposed by the University of Tokyo's Institute of Space and Aeronautical Science. But the most important of this year's anniversaries celebrates an event in 1970. Although their first four attempts to orbit small test satellites were unsuccessful, Japan's persistent space scientists put their 24 kg Ohsumi satellite into orbit in February 1970.

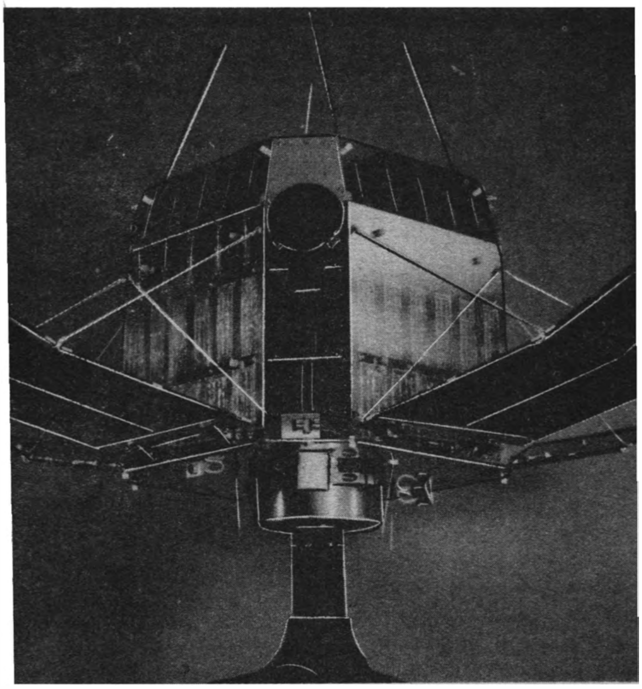
During the past three decades space science has gone through a number of organisational changes and, despite rather modest funding, scientists have managed to build an impressive programme independent from the larger space *applications* programme.

Though the applications-oriented budgetary funding of the National Space Development Agency (NASDA) is about ten times that of the separate Institute of Space and Astronautical Science (ISAS), the space scientists at ISAS are not overshadowed by their NASDA colleagues. The present name, which emphasises 'Astronautical' as opposed to the former 'Aeronautical,' derives from a reorganisation in 1981 that transferred the administration of ISAS from the University of Tokyo to the status of a national inter-university research institute; in a nutshell, ISAS grew too big for a single university.

ISAS stands out as a group of original thinkers and pioneers. Dozens of the engineering specialists working in NASDA received their education under ISAS professors so the mark of ISAS is readily apparent within the larger applications-oriented group. It was ISAS who put the first 'Far Eastern' satellite in orbit, a feat accomplished using domestically-designed and developed technology with the Lambda-4S rocket systems produced by the Nissan Motor Co. and satellite integration work performed by the NEC corporation. ISAS has a record of designing its own equipment and deserves credit for pursuing its own interests without the typical foundation-acquisition purchased through foreign licensing. Since 1970, ISAS has averaged one space launch annually and have met with surprisingly few problems.

Although ISAS uses what some critics say are old-style boosters, the frequently modified solid-fuel Mu-series workhorse (presently in its 28.2 m long MU-3SII phase) is a highly reliable rocket. The scientific work undertaken once the modestly-sized ISAS satellites are in orbit and operational is highly advanced. The 220 kg Tenma (Pegasus), which was orbited in Feburary 1983, has successfully observed galactic and extragalactic X-ray sources, according to Professor Masaru Matsuoka of the space astrophysics research group at the 14th International Symposium on Space Technology and Science in Tokyo.

The 207 kg exospheric explorer Exos-C (more commonly called Ohzora or 'Big Sky'), boosted into orbit by the fourth and final Mu-3S launch vehicle from the ISAS Kagoshima Space Center, is a three-axis stabilised satellite which posses an on-board data processing capability.



The Tenma X-ray astronomy satellite was orbited in February 1983. *ISAS*

Other Projects

NASDA is planning to put its 'First Materials Processing Test' package aboard the Spacelab/Shuttle within a few years, along with a Japanese payload specialist astronaut. ISAS has already flown a large package of experiments aboard Spacelab 1 in 1983.

The University of Tokyo's Nobeyama Radio Observatory (which, like ISAS, is under the jurisdiction of the Ministry of Education, Science and Culture), comprises another group of innovative scientists. The Nobeyama facilities, located more than 1,300 m high in one of Nagano Prefecture's scenic valleys (roughly 150 km due west of Tokyo), were constructed to carry out Japan's foremost radio astronomy work.

Researchers at Nobeyama use a 45 m diameter radio telescope which features a radio spectrometer, as well as an aperature synthesis telescope (for cooperative intercontinental studies with Very Long Base Interferometry) consisting of five antennae, each of a 10 m diameter. The antennae are moveable along two baselines both slightly over half a kilometre in length.

Back at ISAS, the various divisions are considering ways in which they can participate in NASA's Space Station programme. Many ISAS research specialists are interested in the prospect of conducting scientific work aboard the station or within auxiliary 'free flying' modules, according to Professor Kyoichi Kuriki of the space propulsion research division. Some researchers at the National Aerospace Laboratory (NAL, like NASDA, is under the jurisidiction of the Science and Technology Agency) are also considering the feasibility of scientific work to be performed in collaboration with the Space Station.

With their heritage of independently-conceived scientific work and more than two decades of operating the Kagoshima Space Center at Uchinoura, ISAS is moving into a new era in which heliocentric probes and other ambitious spacecraft will contribute to global space science.

THE MYSTERY OF BAYER'S *URANOMETRIA*

By L.J. Carter and A.T. Lawton

The acquisition by the Society of a collection of valuable star maps and the subsequent detective work undertaken to date to discover the identity of its 18th century owner is described in fascinating detail. Publication of a facsimile edition by the Society is planned; details are included at the end of this report.

Introduction

Several years ago the Society acquired a badly-damaged pile of papers, the front sheet being torn at the lower corner and many of the remainder pasted together. A cursory glance disclosed that they were, clearly, old Bayer star maps interspersed with sheets of carefully-catalogued handwritten observations identifying the exact position of each star shown for the Epoch 1747 and with original references identifying certain stars with those that appeared in the earlier star catalogues of Ptolemy, Tycho Brahe and John Flamsteed, the first Astronomer Royal. Preceding Bayer's maps and the additional observations is a handwritten Preface of considerable interest. It had been carefully compiled and is remarkably intact considering the circumstances in which it was discovered. It has been rendered into a printed version to make it more intelligible and is reproduced on the following page. Inevitably, a few words have either been defaced or lost but, by careful reading of the text, those missing can be reinstated. Where this has been done, the word is identified by being placed in brackets thus [].

The mid-18th century spelling and phrasing has been preserved because it gives a unique insight into the private thoughts of a man who must have been prominent, dedicated and yet seemingly humble.

In essence, the writer has taken the basic Bayer maps and inserted all the figures necessary to bring the star positions shown to the corrected values for the year 1747. This is characteristic of a meticulous observer for the original Bayer drawings have many errors - though still engravings of great beauty. When separated, two sheets of handwritten text faced nearly every constellation. The first ('copyed long since' i.e. years ago) reproduces (in Latin) Flamsteed's results. The second records 1747-9(?) observations made by the owner. The arrangement had clearly been done this way for ease of comparison with the constellations and the figures also so arranged that they could be detached to be made into a single large montage to decorate a wall. The use of a star catalogue directly required expertise and sophisticated apparatus not widely available before the 19th century,

Johannes Bayer, the author of *Uranometria.* The drawing is taken from a rare portrait in Munich showing Bayer as he appeared in the late 16th century.

The title page of the Society's *Uranometria* is missing the corner that should have included the date (arrowed, *right*).

so it was apparent that here was the work of a dedicated professional astronomer of high calibre.

Who was this mystery astronomer; where did the star maps come from: where had they been for centuries and how and why had all these further observations been made? Even though apparently a mutilated nondescript set of pages, the result of long neglect, mounting excitement showed that we had found what was akin to a Treasure Chest - almost an Aladdin's Cave.

But it had no key, only some clues.

First Steps

When first acquired, the papers appeared to be firmly glued together by some foreign substance accidentally poured over them. This, when isolated and examined, proved to be jam (either plum or strawberry!), a seemingly trivial domestic accident which played a key role in preserving the original plates and the unknown author's observations.

The first step, clearly, was to attempt to redress the wrongs of ages and to ensure that the pages deteriorated no further. To help in this task the specialist firm of E.A. Weeks & Son was called in and, after what seemed like years, they signalled success. The pages had all been separated and those damaged made whole again, apart from the front Scroll which had lost its lower right hand corner. The second step was to make a high-quality photographic negative of each page, as it was revealed, to ensure that a proper record was kept. At the same time, a start was made on rendering into more readable English the 18th century Preamble which had been added by its mystery owner describing how he had used the

The Handwritten Introductory Notes

"These Tables of Bayers printed for the year 1603, and the Precession of the Equinox being 1 Degree [in 72 years] and the present year 1747 being just twice that period, I therefore proposed to draw a Red line in each Plate 1 Degree and that which being reckoned the true lines of Longitude reduces them to this present AEra.

"And as Flamsteed's Historia Colestis from his actual observations gives the exact situation of each individual star as well as those that had been discovered in Bayers time, as what Flamsteed has added from Telescopical Assistance, I have applied his said Catalogue to make these Tables compleatly useful, which Catalogue being Publisht in the year 1690, I have added to each Longitude 47' 30' which answers the Precession of 57 years, *viz* from the said 1690 to this present year 1747 to which I have also adjusted the Right Ascension, & Distance from the North Pole.

"For example Lyra feu Vista tai* (see Editor's footnote) in which Plate I have drawn a Red Line through 28° Sagittarius & Capricornus for 1st of Point of Aries & Libra; And Lucida Lyrae† in Flamsteed Longitude be Capricornus, 10° 57' 18' by adding 47' 30' makes the present Longitude Capricornus 11° 44' 48'. Then the Right Ascension was 276° 36' 0' & the Variation 36' - 07'. Therefore as 1°: 36' 07' :: 47' 30' : 28' 36,' & 28' 36' + 276° 36' = 277° 4' 36.' And the Variation of the Distance from the North Pole by the same Proportion of 47' 30' to 2' 55' makes 51° 44'. I have added a Column of the Longitude from the 1st of Point of Aries.

"I many years since copyed Flamsteed's Catalogue in Latin on the back of these Plates which made them so very agreeable to my self that I lately came to a Resolution to set about this Present work to calculate the place of each star to the present time to turn the Latin names into English which I had began to do, and pasted my new work to obliterate the old, but soon perceiving my Error I stopt at the 3rd Plate and got my Book new bound up with a spare strip of paper between every one whereby I leave the original of Flamsteed and am thereby enabled to examine any error I may have committed in calculation &c. And also made an improvement by putting the 2 Bears on the one side of the 2 half sheets of interleaved Paper I enabled my self to describe all the Plates in the same size with the Plate itself and then fancyed I had got something worth communicating to the Publick, not only for use but for ornament, thinking were the Figures new engraved and the places of the stars adjusted exactly to the Description, (which by my measuring I have always found agree in Longitude but some few not very nicely in Latitude) they would not only be fit to be bound as these are in a Book, but the Catalogue or Description of such Figure neatly engraved might be ordered so as to be cut in 2 equal parts to be pasted to each side of the Figure, which [I] compute would then be about 15 Inches deep by 21 wide, and that the whole making 48 Pictures Framed neatly would be very orna-mental in a large Room or Gallery; or joining 6 of them in height & 2 wide would make a Leaf of a Screen about 6 & ½ high by 3 & ½ Broad, 4 of which Leaves will take the whole Set of the present Mapp Screens which are very Beautiful and useful occasioned this Thought; These Plates are as so many Celestial Maps, the use of them in many Respects preferred to the Celestial Globe, for as that can be compared only to a general Map of the Terrestrial World, these represent the sep[arate] Kingdoms of the Starry Firmament, and by the use of these nothing is easier attained than the Knowledge of the Constellations.

"And as the greatest part of the Earth has never yet been discovered & infinitely the greatest part of that tho laid down in it [was] never seen by its' inhabitants, we travel the stars with greater ease view them all except those near the south Pole in those clear nights of one revolving year which renders this Science much easier attained than Geography. The Place [of a] Star as to Longitude & Latitude is more exactly seen by these Tables than by the Globe, but that must be applied to [get] the Right Ascension Distance from the Pole.

"The Celestial Globe being an Orthographical Projection of the Constellations, a Person viewing them from it has so Natural an Idea of their Figure as these Tables represent they appearing to him revers't, he is to immagine himself at the Center of the said Machine viewing them through its transparent surface, otherwise his Eye placed above the Starry Hemisphere whereas these Figures are the Natural Position of them as they appear to the Beholder, & in that respect at-table to the Globe, but as they extreamly illustrate each other, 'twere to be wished a new Celestial Globe was made, [the stars] nicely placed from Flamsteed's Catalogue calculated for this AEra of 1747, or any other & market with Bayer's characters, by which 'twould be very easy for the Future to know each Stars exact place on it, as well as in the [sky] by adding 50' to the Longitude for every year from 1747, or 15' for 18 years the Latitude continuing unaltered.

"I had proceeded in my above Design so far so as to finish the Calculation of 11 of these Plates being advised by Professor Bliss of Oxford that Dr Beavis and Mr Neal had prevented me then having already engraved many of the Plates [I] stopt. I would indeed have prosecuted finishing the whole for my own private amusement."

There are further references to Mr Flamsteed but these have been partly obliterated either by Bradley himself or someone else. Underneath is a strip of paper with the following which appears to be in a different hand.

"Mr Flamsteed says that Bayer have drawn all his Human Figures Except Bootes, Andromeda and Virgo with their Backs towards us."

* This is not Latin text and a more likely rendering is "ful Vista talus" viz *looking down the ankle (or foot)* - but the writing is very indistinct.

† "Lucida Lyrae" literally "the brightest star in Lyra" i.e. Vega. According to one authority this is the first time this name or term was used by Bradley. In his nightly observation notes he normally used the star's proper name. Bayer used the name Lucida Lyra for Vega so perhaps, in this case, Bradley followed Bayer's notation, particularly as this had also been followed in the catalogues of Tycho Brahe (reprinted from Kepler's edition of 1628) and of Hevelius, published in 1690.

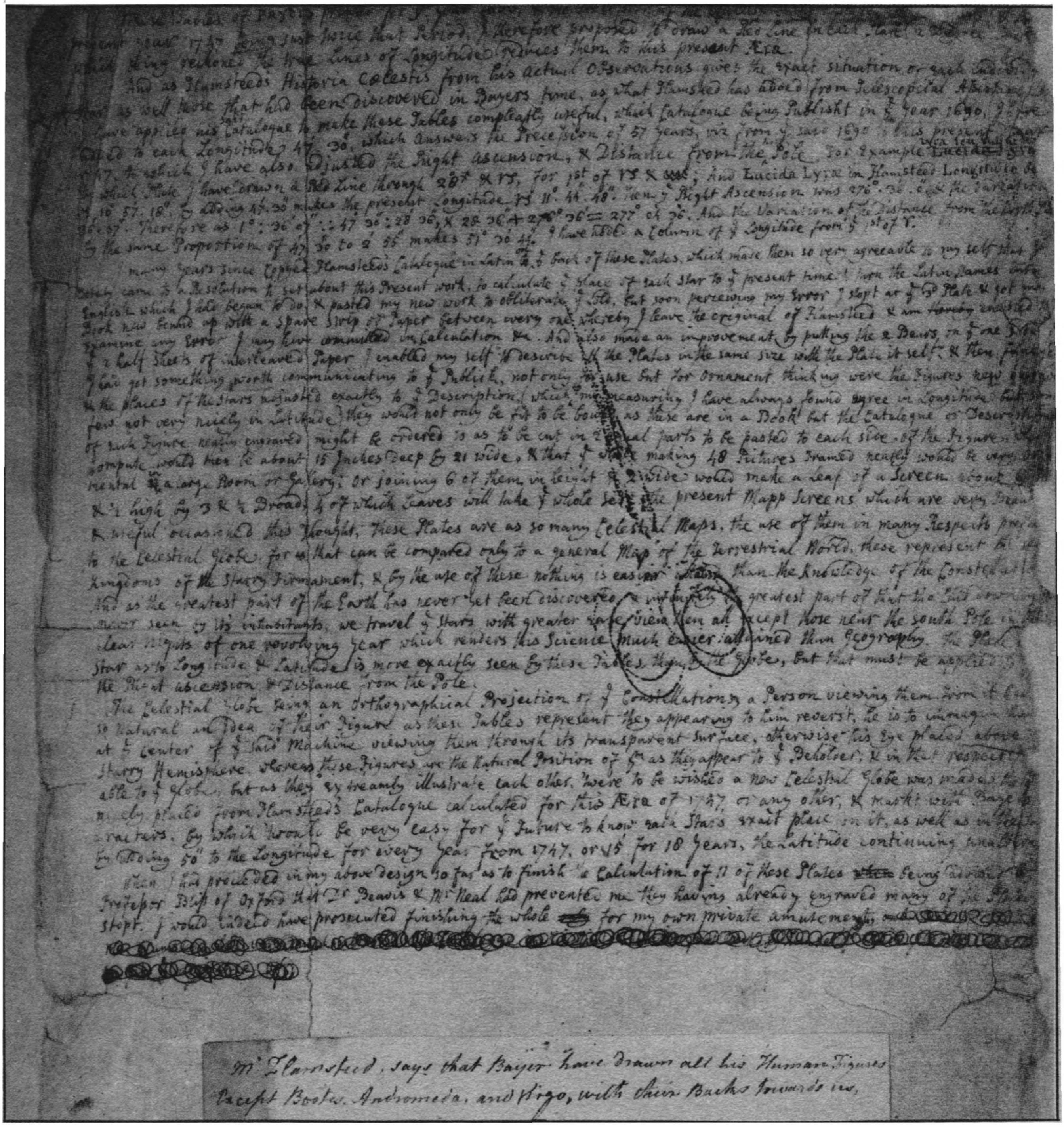
star maps and what his intentions with them had been. These, incidentally, showed that he was familiar with the work of both Flamsteed and John Bevis (both of whom were noted for publication of star maps) and was also in correspondence with Professor Bliss, who subsequently became the fourth Astronomer Royal. Bliss remained in office for only two years. He was then succeeded by Nevil Maskelyne (1732-1811) who was Astronomer Royal from 1765 to 1811 and who played a key part in the mystery by ensuring that astronomer James Bradley's later records were published.

Unfortunately, even the separation of the pages did not bring to light two fundamental matters: *who* was the mysterious astronomer-owner and how and when had he come by the copy of what was then seen to be an edition of Bayer's *Uranometria?*

However, there were a number of leads, all of which required very careful research. One heartening starting clue was the observation made by Messrs Weeks who were convinced that the work was genuine and not a modern clever forgery. The grounds for this belief rested on the knowledge that the solvents used to separate the pages would have destroyed or dissolved a modern red ink, whereas the red lines referred to in the Preamble retained all their original brightness.

The *Uranometria* of Bayer

The *Uranometria* (Atlas of the Heavens) first appeared in the year 1603. Its author was a Bavarian lawyer, Johannes Bayer (1572-1605). This very important work


Mr Flamsteed, says that Bayer have drawn all his Human Figures
Except Bootes, Andromeda, and Virgo, with their Backs towards us,

The handwritten introduction to the Society's copy of *Uranometria.*

was such a boon to astronomers that it continued as a major work of reference throughout the 17th and 18th centuries.

Basically it consisted of a finely-engraved frontispiece with 51 copper-engraved star maps recording the approximate positions and magnitudes of some 500 stars observed by Bayer himself, in addition to those that had formed the renowned catalogue of the Danish astronomer, Tycho Brahe, only a year earlier. Although adopting, without question, the magnitudes and positions of Tycho's stars, it gave - for the new stars - the magnitudes (brightnesses) that Bayer had recorded himself. He also adopted a system of notation* to distinguish the *degrees* of brightness, based on the Greek alphabet† *viz:* alpha, beta, gamma, etc, using the six orders of magnitude handed down from antiquity and thus resolving a problem that had always been one of great difficulty. Bayer, himself, says that there are 1706 constellation stars of these magnitudes, plus 325 that are 'scattered' i.e. not clearly in identifiable constellations.

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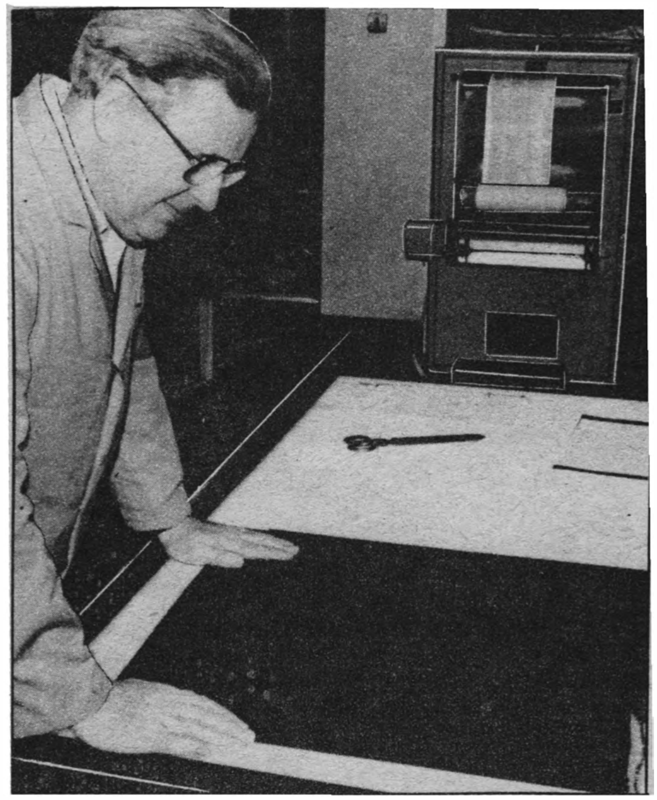
* The full description of stars in the Bayer system consists of the Greek letter followed by the possessive of the Latin name of the constellation. Where the known stars in a constellation exceed the number of Greek letters, Bayer then adopted the Roman alphabet as far as was required, though he never used any capital *letters apart from* A, *which he invariably adopted whenever he used the second alphabet.*

† In ancient catalogues stars were identified by the part of the constellation in which they appeared e.g. "The Eye of the Bull." Later, the Arabs gave special names to most of the brighter stars, some of which still survive though most have dropped entirely out of use.

John Flamsteed, the first Astronomer Royal. RGO



Producing negatives of the original for printing purposes.

He also added a dozen new constellation figures, all in the South. According to later writers he obtained the data for these from two Dutch navigators, Petrus Theodori and Friedrick Houtmann. The attractive constellation figures were not original to Bayer but were derived from those drawn a few years earlier by Jecobo de Gheyn.

Printed on the backs of the 48 maps of the individual Ptolemaic constellations (i.e. Serpens is on one map while Serpentarius is on another) - on almost all copies, but not on ours - is a discussion of various names for that constellation and a catalogue of stars which includes the Ptolemaic number, the Bayer letter and magnitude and position within the constellation figure.

Four *clusters* of stars appear in Bayer's maps, distinguished by a *single* letter only *viz* tau Sepentis (eight stars), tau Eridanis (nine), nu Eridanis (seven), and pi Orionis (six).

Flamsteed in the preface of his *Atlas Coelestis* (1729) says of Bayer's maps:

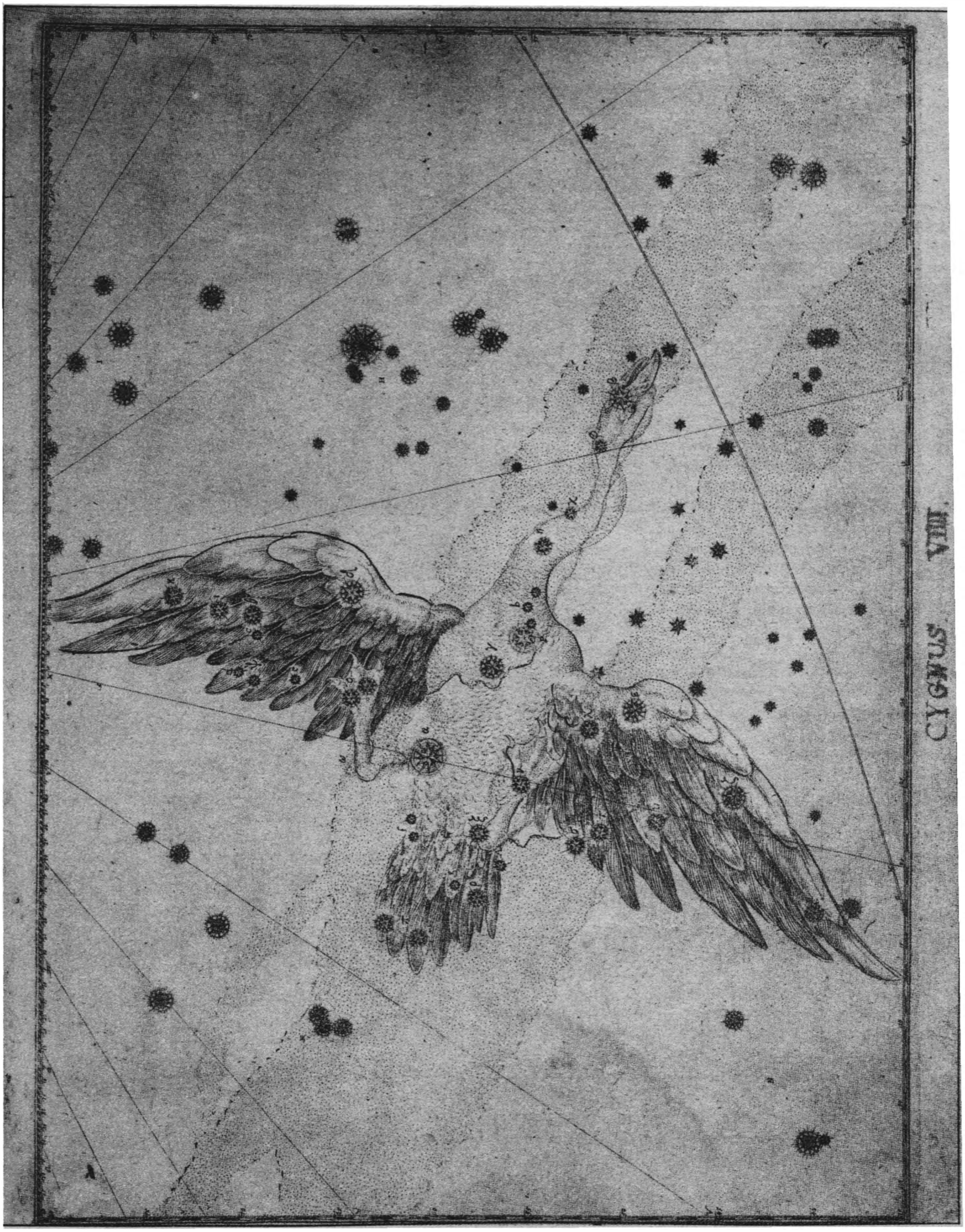
"*Tycho Brahe* died in the Year 1601, two Years after Bayer pub-lish'd his *Uranometria,* wherein he gives us Maps of all the Const-elations: His Figures are tolerable, and the Stars rightly laid down according to their Place in *Tycho's* Catalogue, and many other small Stars are added which it hath not: These, 'tis probable, he inserted upon his own *bare* View, by comparing them with the Fixed Stars inserted in his Maps from *Tycho's* Catalogue, whose *Nomenclatura* is the fame; but having drawn all his *Human Figures,* except *Bootes, Andromeda,* and *Virgo,* with their Backs towards us, those Stars, which all before him place in the *Right* Shoulders, Sides, Hands, Legs or Feet, fall in the *Left,* and the contrary in his Figures; with which therefore whosoever goes about to examine the *antient* Observations, or the Catalogues of the Fixed Stars, printed or publish'd in any Language, will find himself much perplexed, if he be not before-hand apprized of this.

"Nevertheless, in most of the Maps of the Fixed Stars that have been Engraved since those of *Bayer,* the Forms are taken from him, and have the fame Faults with his."

Subsequent editions of Uranometria appeared in 1639, 1648, 1655, 1661, with other reprints and re-issues from 1697 to 1723. Additionally, the plates were issued without accompanying text at Augsburg in 1624 and at Ulm in 1639, 1641, 1648, 1655, 1661, 1666 and 1689. In addition, Bayer's text, i.e. without the maps, was published at Strasbourg in 1624, at Augsberg in 1654 and at Ulm in 1640, 1697 and 1723. This surfeit of information led to Delambre, referring to Bayer at a later date, saying icily: "No man ever acquired immortal fame at so little sacrifice and with so little trouble!"

The front Scroll, unfortunately torn on our copy, shows several allegorical figures. On the left is an old man pointing to what is, apparently, an ancient map. On the right is a figure with a globe and at the base is a panoramic view of the city of Ulm. Missing through damage is a small heraldic device with the engraver's initials and the date of printing, though it was clear that the cherub appearing in the lower centre of the Scroll had been used in the first edition but replaced in later editions. Furthermore, the constellation figures themselves had been printed with altered emphasis; whereas those appearing in other copies emphasised the outline of the mythical constellation figures, in our copy these were greatly subdued and the emphasis placed on the stars, which stood out very clearly. Those, obviously, would have been more important to a practising astronomer than mythical constellation symbols. Presumably, this might have been done deliberately and the Catalogue purposely selected by a practising astronomer. Only more decorative versions would have been purchased by those wishing to make an impression, as opposed to actually using them for serious observation.

This implied that the edition was that of 1624 i.e. the first known edition of the plates without any Latin text, even though the stars were quoted as being applicable to the Epoch 1603, the date of the first edition. If 1624 was right the mysterious owner could also have possessed a copy of the text published separately at Strasbourg that



The representation of the constellation of Cygnus in *Uranometria.*

same year though this would soon have been discounted by him in his marathon task of surveying every star.

Events then took an unexpected turn. Added fortuitously to our Library stock was an 1845 catalogue of star positions prepared for the British Association for the Advancement of Science and edited by Francis Baily. This was a most arresting work compiled after extremely diligent study. In its introduction (p.67 onwards) it referred to the work of James Bradley, the 3rd Astronomer Royal and says "Bradley has tried to compare the stars with the earlier catalogue of Flamsteed"* (which tallies with

* Bradley's early labours at the Royal Observatory did consist almost wholly of a complete re-observation of the stars in Flamsteed's catalogue, reduced to the year 1744.

the work in our copy of *Uranometria*) and then goes on to say (referring to various errors by Flamsteed) that these arose "probably from his having only the *maps* of Bayer, *without the letter-press* printed at the back." (Footnote on p.69).

Thus emerged the statement that Flamsteed, the first Astronomer-Royal, used the *Uranometria* Star maps *alone* (i.e. without Latin text) and in exactly the same manner as we may now attribute to one of his successors.

It then goes on to add by way of a footnote, "There are many copies of this imperfect edition in existence: they bear the same date (1603) and appear to be printed from the same plates as the perfect edition."

Thus, at last, emerges a clear statement which dates our copy to 1603, i.e. the date of the first edition and accords with all the facts discovered to date.

Who Was the Mysterious Owner?

Telescopes in the 17-18th century were notoriously poor and cumbersome in character. The number of assiduous astronomers with access to suitable instruments *and* the skill and dedication needed to observe the passage of stars across the meridian night after night is little more than a handful. Those fitting this description include Molyneaux, Mason and a few others, but the central figure who bestrides the scene was James Bradley, third Astronomer Royal, noted for assiduous stellar observations which occupied most of his life and which were still used as the bases of calculations and comparisons by astronomers more than a century afterwards.

But first, an examination of Molyneaux's writing showed no comparison and eliminated him altogether. Charles Mason (1730-1787), Bradley's assistant, at a salary of 26 shillings (£1.30) per year, was later to become famous as one of the two men engaged by Lord Baltimore and Mr Penn to settle the boundary between Maryland and Pennsylvania, i.e. the famous "Mason-Dixon Line." Mason, however, could be ruled out as well. He did not start at Greenwich until 1756, far too late to have been employed in the 1747-9 observations. The same went for his successor, Charles Green. A certain Gael Morris crops up as assisting Bradley, but he is only a shadowy figure who, apparently, did no important work.

Who else is left?

It transpires that soon after James Bradley went to Greenwich in 1742 he employed John Bradley as his assistant, John being the son of his eldest brother. John, who remained with his uncle for 14 years, was born about 1728 and "had the advantage of the very best instruction and executed his great master's plans with unwearied diligence." The date of the last observations recorded in his hand is September 1756, after which he went to sea.

John, obviously, during the 1747-9 period was 19-21 years of age and could not possibly have made the observations himself. He was far too young and inexperienced and, at most, would have done no more than "execute his great master's plan." With the young John as his one and only assistant thus eliminated, no other obvious candidates are left.

The next quest, therefore, was to research into the life, times and circumstances of James Bradley himself. This took us on a visit to the Royal Greenwich Observatory at Herstmonceux where substantial records of James Bradley are kept together with a detailed biography, a portrait and instruments used at Greenwich with which Bradley would have been familiar, particularly the clock by George Graham.

But first, about the man himself.

James Bradley

James Bradley was descendant of a family seated at

Dr. Rev. James Bradley. *Royal Greenwich Observatory*

BRADLEY'S DISCOVERIES

Bradley's discoveries of aberration and nutation provided, for the first time, an exact knowledge of the places of the fixed stars and, thus, the movements of other celestial bodies.

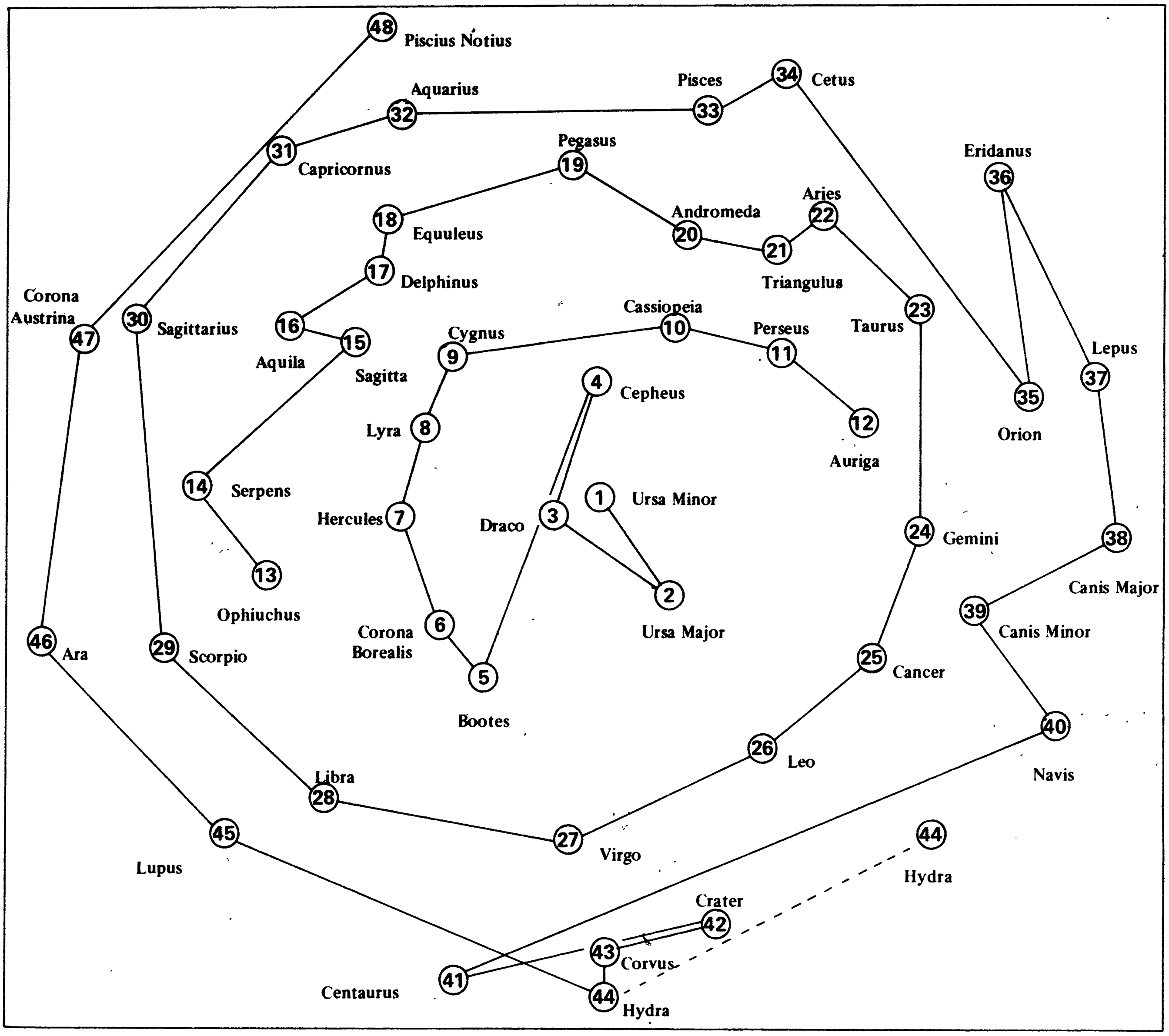
1. The Aberration of Light

While attempting to measure the parallax of stars, Bradley came to realise that his results were being disturbed by an effect that he later identified as the aberration of light. The observations that led to this were made through a telescope erected on 26 November 1725 at a house then occupied by Samuel Molyneux on the western extremity of Kew Green in London. The instrument used had a focal length of 24 ft 3 in (7.39 m) and an eye-glass held 3½ ft (1.1 m) above the ground floor.

He was observing the star Gamma Draconis close to his zenith. On 17 December, when he expected to see it shifted northwards in the sky because of parallax, he was surprised to see a definite change to the south. Over the next year he observed the star and found its movements to be directly opposite to those expected from parallax. He then studied several other stars with a new telescope at Wanstead and found the same effect. The explanation dawned on him one day while in a sailing boat: he then realised that the combination of the wind and the boat's velocity was similar to the light from a star and the Earth's motion. He published his result in 1729. So accurate was this that his constant of aberration was never disputed and has scarcely been corrected ever since.

2. Nutation of the Earth's Axis

Bradley found that, even when allowing for a star to complete the movement due to aberration, it did not return *exactly* to its same position of 12 months earlier. He had discovered that the Earth's axis 'wobbled' slightly instead of precessing smoothly through space as believed. Bradley traced the cause to the attraction of the Moon and its 19-year orbital cycle acting on an irregularly-shaped Earth.



A simple map of the constellations and their order in the Society's copy of *Uranometria*.

Bradley Castle in County Durham. His father, William Bradley, had married Jane Pound in 1678. James himself was born in 1692 or 1693 at Sherborne in Gloucestershire and educated in the Grammar School at Northleach, entering Balliol College, Oxford, on 15 March 1711. Much of his time as an undergraduate was passed with his maternal uncle, the Rev. James Pound, Rector of Wanstead in Essex, who was not only a well-known man of science and diligent observer of the stars but probably one of the best astronomical observers in England at that time. The first example of Bradley's astronomical skill became evident in two observations made in 1717-18, published by Edmond Halley who had immediately perceived the extraordinary scientific talents of the young astronomer.

Bradley's reputation as an astronomer increased so rapidly that, on 16 November 1718, he was elected a Fellow of the Royal Society. Astronomy at the time was not sufficient to support him financially and in 1719 the Bishop of Hereford offered him the Vicarage of Bridstow, near Ross in Monmouthshire. On 25 July 1720, having taken priest's orders, he took over the vicarage. It appears that his clerical work was not very demanding for he was frequently able to pay long visits to Wanstead until his uncle died on 16 November 1724.

The time quickly arrived when Bradley was able to devote himself wholly to astronomy. In 1721 the Savilian Professorship of Astronomy in the University of Oxford became vacant but the statutes required him to resign his clerical appointment before he could accept. This he did, though he remained a priest and regularly assisted his uncle as curate, and from that time on he devoted himself entirely to his favourite science.

On 26 April 1722 he read his inaugural lecture in his new position and soon became widely known as a highly diligent observer, even though the state of knowledge of telescopes of the time forced him to use an instrument with a focal length of 122-124 ft - the objective glass being held on top of a pole! He observed, for example, the transit of Mercury across the Sun's disc on 9 October 1723, measured the diameter of Venus and assiduously observed from Wanstead for six weeks a comet discovered by Halley on 9 October 1723 (the first of Bradley's remarkable contributions to the *Philosophical Transactions* concerned this comet). Even if he had left to posterity only his Greenwich observations, his fame might have rested on the skill and care shown in compiling them.

In 1725 George Graham erected a 24¼ ft (7.39 m) zenith telescope at the house of Bradley's colleague Samuel Molyneux at Kew near London. It was with

this instrument that the first of his two fundamental discoveries was made. Observations made over some years led him to realise by 1728 that the annual variation of some 40′ of arc in the declination of Gamma Draconis was an effect of the orbital velocity of the Earth, this causing a shift in the apparent position of the star. The effect became known as the aberration of starlight and was the first proof of the Earth's motion around the Sun in space and hence of the validity of the Copernican solar system.*

It was also the second demonstration of the finite velocity of light and led to a determination of its value which, within the limits of the then accepted figure for the solar parallax, agreed with Ole Rømer's value, inferred from the annual variation in the apparent timing of the phenomena of Jupiter's satellites. The reasoning followed by Rømer in explanation of his observations had not been fully accepted by the scientific community, even 50 years after he made his announcement. Bradley's confirmation served to remove any remaining opposition to the logic behind Rømer's explanation.

Not all the observations used in this demonstration were taken at Kew. In 1727 George Graham constructed a 12½ ft (3.81 m) zenith telescope at the house of James Pound's widow in Wanstead and this was the instrument which Bradley most relied upon. In later years it was removed to the Royal Observatory but at this time it was used in Bradley's investigations into aberration.

The aberration of light, announced in 1729, the greatest achievement in positional astronomy in the 18th century. It proved to be so important that when Halley, the Astronomer Royal, died on 14 January 1742, Bradley was appointed his successor on the recommendation of being "the best astronomer in Europe." On taking his place at Greenwich on 3 February 1742 he was unable to make useful observations because the condition of the instruments there was so poor, so he personally undertook their repair. His first transit observation was made on 25 July 1742. The work done in 1743 was enormous. With the addition of a finer micrometer screw on 18 July 1745 he succeeded in measuring intervals of half a second and at various times between 1743 and 1749 he made many experiments on the length of the seconds pendulum.

By September 1747 he was fully satisfied with the series of observations made over 20 years and which had confirmed his second great discovery - the Wanstead observations of the 1720s, demonstrating aberration, had indicated to Bradley the existence of another polar motion. As lunar nutation was suspected, he waited for a full lunar synodic cycle to elapse before publishing his results - the nutation of the Earth's axis. These he published on 14 February 1748 and in August of that year he secured funds to acquire an 8 ft mural quadrant on which he built the firm foundations of modern practical astronomy.

These two discoveries placed Bradley among the most important astronomers of all time.

The year 1749, i.e. the date when the mysterious observations end, proved particularly significant for Bradley, for this was the date when a grant of £1,000 was made by King George II - a grant which opened up a flood of new opportunities. For example, soon after becoming Astronomer Royal, Halley had installed one of the first Transit instruments to be used in England. This was a 5 ft telescope mounted off-centre. Bradley replaced Halley's Transit with a new one bought out of his 1749 grant and installed it on stone piers erected in the Transit

Edmond Halley, an important figure in Bradley's career.
Royal Greenwich Observatory

Room of his new observatory. It was first used on 2 September 1750.

Bradley's brass Quadrant was made by John Bird and purchased also out of the 1749 grant, to a design similar to that of Halley's Iron Quadrant. It was delivered on 16 February 1750 and fixed on the Quadrant wall of the new Observatory shortly afterwards. Like Halley's, the Quadrant was 8 ft radius. Also in 1749 Bradley moved his 12½ ft zenith sector, made in 1727 by George Graham, to the Royal Observatory, also out of this grant. Bradley's zenith sector remained in the Quadrant Room until 1837 when it was taken down and shipped on temporary loan to the Cape of Good Hope. It was subsequently returned and is now exhibited in the Octagon Room of the Old Royal Observatory.

Despite his relatively primitive instruments, Bradley produced masses of careful measurements which proved invaluable to later astronomers. Some were used in orbital calculations for the Moons and planets; those for 3222 stars were formed into a catalogue published by the German astronomer Bessel in 1818 under the appreciative title of *Fundamenta Astronomiae*. The same data were used yet again 70 years later in work on the proper motion of stars. He very nearly discovered the nature of true double stars in 1718 when studying the movement of the star, Castor. Sadly, he was diverted and the discovery of double stars fell to William Herschel who showed, in publications in 1782, 1785 and 1821, that some 848 stars were truly double. Had Bradley pursued his studies of Castor the universal nature of Newton's Laws of Gravitation would have been made while Newton was still alive (Newton died in 1727). Almost certainly, such a discovery would have stimulated Halley to act further in his own attempts to prove the universality of Newton's Laws - the investigations that led to his predicted return of the comet which now bears his name.

* A dial, erected in 1831 by the Command of King William IV, marks the spot at Kew where Bradley began the observations which led eventually to his two major discoveries.

Astronomers Referred to in the Text

Ptolemy. Little is known about Ptolemy apart from the fact that he lived in or near Alexandria in Egypt. His observations appear to span the period 127-151 AD and his monumental work, the *Almagest* was written about 150 AD. (Ptolemy did not actually use this title. He called it *The Mathematical Collection*). His catalogue covered 1,028 stars (three are duplicates) grouped into 48 constellations *viz* 12 in the Zodiac, 21 in the North and 15 in the Southern hemisphere. So important was the work of Ptolemy that all other star tables for more than 1,400 years afterwards were based on his results.

Ptolemy's list could have been based on an earlier catalogue by Hipparchus in the second century BC, though this, and any earlier catalogues, have been lost.

An analysis of Ptolemy's *Almagest* by Halley had shown that several nearby stars had intrinsic, or proper, motions. The detection of proper motions became an important feature of 18th century astrometry, as it is today, and the great accuracy of Bradley's observations was essential in establishing this stellar movement.

Tycho Brahe (1546-1601) made the first extensive star catalogue since the work of Ptolemy, more than 14 centuries earlier, at his private Observatory on the island of Hven, Denmark. Tycho's instruments were most rudely divided. Moreover, he had no clock or micrometer and only a rudimentary knowledge of the motions of the heavenly bodies. His catalogue of 777 stars was published in 1602. An extended catalogue of 1,005 stars was circulated in manuscript form in 1598 and published later in tabular form by Kepler in 1627.

John Flamsteed (1646-1719) was appointed in 1675 to the newly-created post of Astronomer Royal. There he compiled the first telescopic catalogue of the positions and magnitudes of northern stars. This was then an untrodden path for Flamsteed was one of the first who made use of a telescope for such astronomical observations; at the time he began the only catalogue in existence was that of Tycho Brahe - whose observations had been made with the naked eye and coarse instruments. Flamsteed's catalogue of 2935 stars (including some duplicated and others not subsequently found), still unfinished at his death, was published by his friends along with other observations in 1725 in *Historia Coelestis Britannicae.* To accompany the catalogue was *Atlas Coelestis,* a set of 25 maps centred on the major constellations visable from Greenwich from magnitudes 1-7, with the brighter ones identified by Bayer's Greek letters, which appeared in 1729. This catalogue was important because, for the first time, the stars within each constellation were arranged according to increasing Right Ascension. In 1783 the French astronomer Lalande, in his edition of Flamsteed's catalogue, fixed consecutive numbers to the stars but these so-called "Flamsteed numbers" which have since been widely used by astronomers do not appear in Flamsteed's original catalogue or maps!

John Bevis (1693-1771) was a close friend of the instrument makers George Graham and James Short. During the 1740's Bevis began a new celestial atlas patterned after Bayer's, with the addition of stars catalogued by Hevelius, Halley, Flamsteed and Bevis himself. Subscription for the atlas was announced in 1748 and although a few copies of the printed pages were circulated privately around that time it was not officially published until 1786, the delay being attributed to the bankruptcy of the publisher, John Neal. His copper plates were sequestred by the Courts and did not reappear. Some of the printed sheets were auctioned after 1785 and some sets assembled, but only 12 are known to exist today.

The title page is particularly moving. It reads: "The Expence of the Engravings was *Immense,* as the most Capital Artists in *Europe* were employed in executing them... the heavy Charge attending it rendered some of them Insolvent, others were removed by Death which with diverse adverse Occurrences were the Means of retarding the Publication until the present period."

NATHANIEL BLISS.
(From an engraving on an old pewter flagon.)

The atlas contains 51 copper plates: 48 are of the Ptolemaic constellations, one is of the skies round the south equatorial pole and two are hemispheric maps.

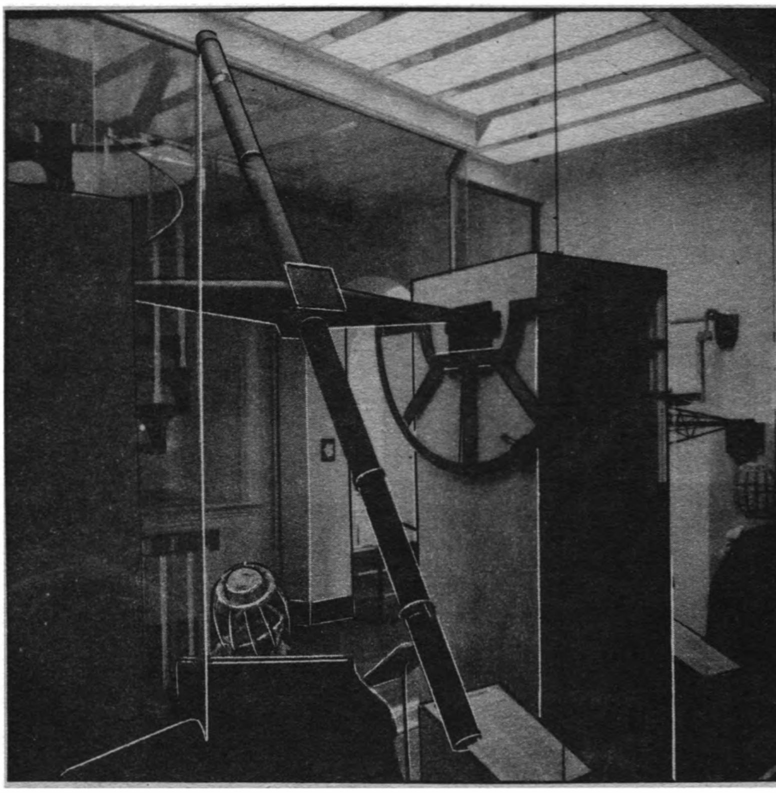
Nathaniel Bliss (1700-1764). When James Bradley died in 1762, Nathaniel Bliss was the obvious choice of successor: the two men had been in regular correspondence for 20 years and Bliss had, on some occasions, assisted Bradley with observations at Greenwich.

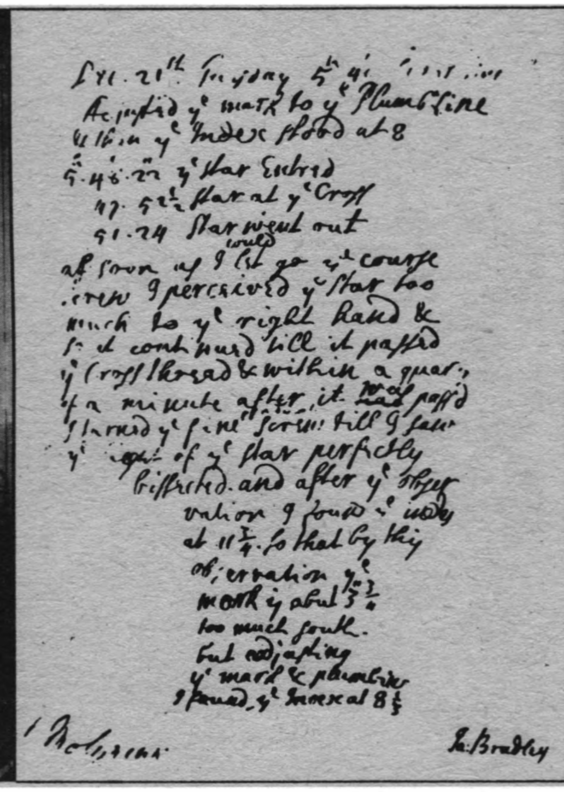
He always had considerable mathematical abilities but his early career was in the Church, becoming Rector of an Oxford parish in 1736. On Halley's death in 1742 he was appointed Savilian Professor of Geometry and it is from this time that the correspondence with Bradley dates, Bliss becoming a Fellow of the Royal Society in the same year. One of the first items communicated by Bliss concerned observations of the Jovian satellites, and reflected one of Bradley's principle interests.

Bradley was in such poor health at the time of the 1761 June transit of Venus that he was unable to make any observations. The vital Greenwich observations of this event were made by Bliss, some of Bradley's written instructions for the phenomena being preserved with Maskelyne's papers.

With the personal knowledge that he had gained working with Bradley at Greenwich, Bliss was the natural successor to the post of Astronomer Royal and was appointed soon after Bradley's demise in 1762. Unfortunately Bliss was in office only two years as he himself died on 2 September 1764, thus making only a slight impression on the history of the Royal Observatory.

Nathaniel Bliss remains an insubstantial figure in the history of the Royal Observatory; his tenure as Astronomer Royal was too short to have any lasting impact on the running of the Observatory and it was left to Nevil Maskelyne to make the innovations and publish the volumes which would, after one century of work at Greenwich, bring the labours of Flamsteed, Halley and Bradley to fruition.





Dec. 21st Friday 5h 4'
Adjusted ye mark to ye Plumb Line
when ye Index stood at 8
5.48.22 ye Star Entred
47.52½ Star at ye Cross
51.24 Star went out
as soon as I could go ye course
over I perceived ye Star too
much to ye right hand &
it continued till it passed
ye Cross thread & within a quar.
of a minute after it was passd
I turned ye fine screw till I saw
ye light of ye Star perfectly
bisected. and after ye obser-
vation I found ye index
at 11¾. so that by this
observation ye
mark is about 3¾
too much South.
but adjusting
ye mark & plumbline
I found ye Index at 8½

Ja: Bradley

Left: Bradley's transit instrument, preserved at Greenwich and, *right,* notes made by the astronomer during the course of his observations.
Royal Greenwich Observatory

Towards the end of his career Bradley was able to see spectacular proof of the prediction made by his mentor and friend, Edmond Halley, in the appearance of the comet at Christmas 1758. The observations of Halley's comet in 1758/9, recorded in short pieces in Bradley's notes, serve as another reminder of his predecessor's influence. The transit of Venus expedition to St Helena and Maskelyne's observations there are also preserved with the Bradley papers and are evidence that Bradley again kept faith with Halley in arranging for the observations to be made.

Though by 1760 Bradley was seriously ill he was still able to draw up instructions for the observations of the transit of Venus in 1761 which Halley had been so insistent should be observed by the younger men of his day. Bradley wrote a detailed memorandum to Charles Mason for his transit expedition to the East Indies and he was also responsible for sending Maskelyne to St Helena to observe the event. It is tragic to relate that when the great day came he was too ill to make observations from Greenwich, though Nathaniel Bliss, who was to be next Astronomer Royal, was present and saw the transit from the Royal Observatory.

Little is known of Bradley's private life. On 25 June 1744 at the age of 51 (soon after he became Astronomer Royal) he married a daughter of Samuel Peach of Chalford in Gloucestershire, some 25 years his junior. She appears to have been a person of great strength of character and determination and played a principal part in the legal arguments that followed Bradley's death. Their only child became the wife of her cousin, Rev. Samuel Peach, rector of Compton, Beauchamp in Berkshire. Thus, no direct descendant of Bradley survived.

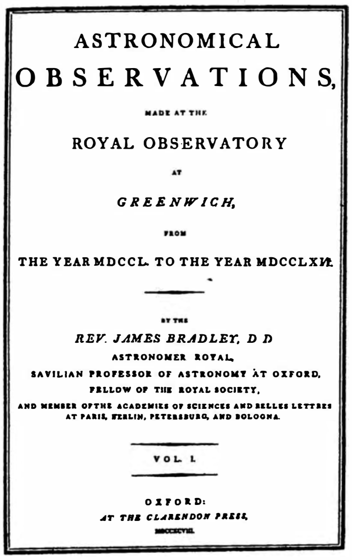
Bradley's last two years of life were clouded by depression brought on by apprehension that he should become senile. Some authorities list Bradley's death as taking place in "unusual circumstances," but a more detailed acount indicates that he fell off his horse while taking a ride to clear "pains in the belly and head." However, he retained his mental powers to the end. He died on 13 July 1762, aged 70, and was buried at Minchinhampton in Gloucestershire. Lyson, Bradley's doctor, described the latter's death and the autopsy carried out afterwards. (*Phil. Trans.* Dec 1762 pp.635-640). No cause of death was ascribed to the case though modern opinion is that Bradley suffered from tuberculosis of the kidneys.

He was succeeded by Dr. Nathaniel Bliss of Oxford (1700-1764) who became the fourth Astronomer Royal, as already recorded.

Fitting the Pieces Together

Prior to the visit to Royal Greenwich Observatory, a number of things remained to be done. First was the watermark of the paper used by the mysterious owner. This turned out to have a Royal watermark, indicating that the owner had access to Government-issued paper by virtue of his position. This watermark was GIR (i.e. George the First). This was appropriate for Greenwich Observatory and thus indicated James Bradley or one of his Assistants. The long-standing interest of Bradley in astronomy had been augmented by his uncle, James Pound (1669-1724), which suggested that the first owner of the Bayer Atlas might have been Pound himself who had, in turn, passed it over to his nephew. Another clue emerged with the discovery that the first collection of observations published by James Bradley covered a period *later* than those in our volume. Whereas those in the Bayer Atlas related to 1747-8 (or 9). Bradley's observations made at the Royal Observatory at Greenwich, as published by the Clarendon Press, Oxford, covered the years 1750 to 1762. They occupied 931 large folio pages and cannot number less than 60,000 observations. They did not actually appear until 1798. It appears that earlier but unpublished observational records are held at Herstmonceux which cover the period 1742-1749, which we have still to examine. (Basically, there was a dispute about who actually owned Bradley's observations, even-

The Title page of the 1798 book covering Bradley's observations from 1750 to 1762.



ASTRONOMICAL
OBSERVATIONS,
MADE AT THE
ROYAL OBSERVATORY
AT
GREENWICH,
FROM
THE YEAR MDCCL. TO THE YEAR MDCCLXII.

BY THE
REV. JAMES BRADLEY, D.D.
ASTRONOMER ROYAL,
SAVILIAN PROFESSOR OF ASTRONOMY AT OXFORD,
FELLOW OF THE ROYAL SOCIETY,
AND MEMBER OF THE ACADEMIES OF SCIENCES AND BELLES LETTRES AT PARIS, BERLIN, PETERSBURG, AND BOLOGNA.

VOL. I.

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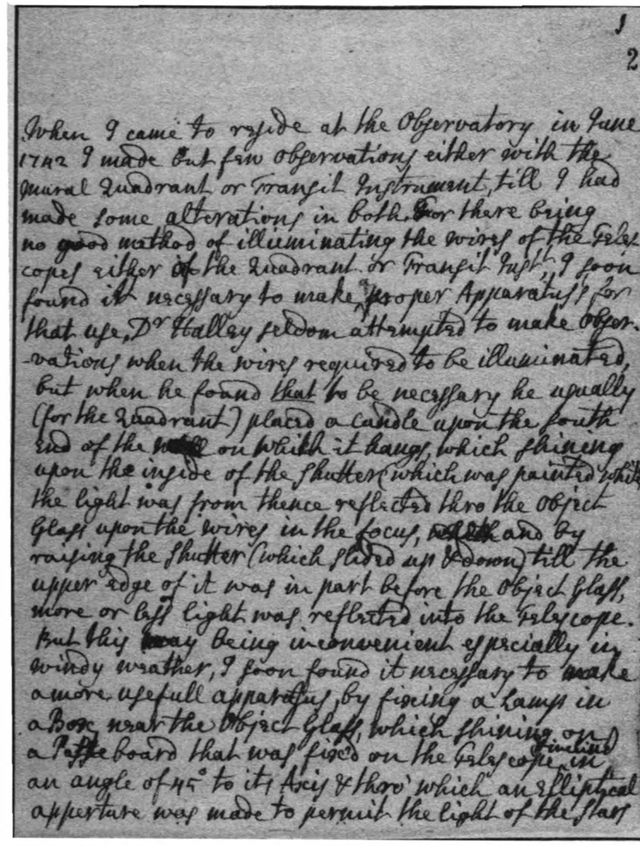
MDCCXCVIII.



1
2
When I came to reside at the Observatory in June 1742 I made but few observations either with the Mural Quadrant or Transit Instrument, till I had made some alterations in both. For there being no good method of illuminating the wires of the Telescopes either of the Quadrant or Transit Instrt, I soon found it necessary to make proper Apparatus's for that use, Dr Halley seldom attempted to make observations when the wires required to be illuminated, but when he found that to be necessary he usually (for the Quadrant) placed a candle upon the South end of the wall on which it hangs, which shining upon the inside of the Shutters which was painted white the light was from thence reflected thro the Object Glass upon the wires in the focus, and by raising the Shutter (which slided up & down) till the upper edge of it was in part before the Object glass, more or less light was reflected into the Telescope. But this way being inconvenient especially in windy weather, I soon found it necessary to make a more usefull apparatus, by fixing a Lamp in a Box near the Object Glass, which shining on a Pasteboard that was fixed on the Telescope inclined in an angle of 45° to its Axis & thro' which an Elliptical apperture was made to permit the light of the Stars

An example of James Bradley's handwriting from 1747, when he was 54 years old. *Royal Greenwich Observatory*

tually ending with a law suite.) Even so, his 1750-62 positions were so important that they were used again by F.W. Bessel in his *Fundamenta Astronomiae pro anno 1755* in 1818. This work gave the proper motions of the stars, as derived from many of the observations of Bradley and constitutes a milestone in the history of astronomical observing for, until then, the positions of stars were not known so precisely. It was said afterwards that "Bradley's observations were made to mark the beginning of modern astrometry." These star positions, determined by Bessel from Bradley's observations, were essential in calculating the positions for one century in his *Tabulae Regiomontanae* (1830), which provided the first modern reference system for the measurement of the positions of the Sun, Moon, planets and stars.

Independent evidence showed Bradley to be a perfectionist and extremely loath to publish *anything* until completely satisfied as to its accuracy. He was always more afraid of injuring his reputation than enhancing it and he shrank from publicity. This was confirmed by a book published in Oxford in 1831. This work, by Professor S.P. Regaud, was a large quarto volume with the title of *Miscellaneous Works and Correspondence of James Bradley, Astronomer Royal.* This embodies all that could be gleaned about him by the closest enquiry *and brought to light details of his early observations after nearly a century's oblivion.* These observations were ranked as so important that a posthumous prize was then awarded to Bradley by the Royal Society of Copenhagen.

But why did Regaud omit the 1742-9 observations? An explanation that he saw no point in publishing them does not ring true when he went to such trouble to include everything else. This is, clearly, an area for further study.

One could speculate that the answer to the mysterious observations lay with the nephew John Bradley. One might speculate that the Bayer Atlas had originally been handed to James Bradley by his uncle, James Pound and then, handed in turn, to the young John Bradley. Little is known of John after his work at Greenwich other than that he went to sea and in 1769 was at the Lizard to observe the transit of Venus for Maskelyne. But what happened after that? Was he lost at sea, the atlas then passing through the years as a piece of flotsam until it reached the Society? Such a course of events could be feasible but founders on the very important fact that the writing, clearly, was not his!

But was it *James* Bradley's handwriting? Surely it would be possible to identify this beyond doubt simply by comparing it with known specimens. This was the main purpose of the visit to Herstmonceux. It had become clear from examining the originals very closely that two periods in the handwriting were involved and, although these looked strikingly dissimilar, the owner's preface stated quite clearly that he had written both! Without such a statement, one would have been hard put to argue that a single person was involved, even allowing for a tendency for the tabular material to be made as nearly as possible to look like printing.

Graphology

The first matter to be settled on arrival at Greenwich was the comparison of the two types of handwriting in Bayer's *Uranometria* with specimens of other handwritten records at Greenwich at that time. Examination, however, showed both similarities and differences. No overall pattern emerged though the letter 'd,' among others, was identical to the flourish used by Bradley at all times. In other respects, even the same letter was sometimes similar but sometimes different. It seemed that the writing had differed yet again with advancing years - as it had done in the two styles recorded in the book. Comparison with other potential candidates, however, showed conclusively that there was no comparison at all. This matter of divergent handwriting appears to have upset Delambre, who we previously met castigating Bayer. This time he appears to have been put out by a description of Bradley as being "without compare" for, amongst other objections, he casts doubts on the handwriting recording Bradley's observations in the following terms:

> "It is impossible that the doubt can even now be removed for the observations were not of necessity copied into the books by the same person who made them and *the difference in handwriting will lead to no conclusion.*"

Friends of Bradley responded by pointing out that "both for the better continuance of his labours and the accuracy of the performance," e.g. if meridian observations had to be carried out simultaneously at the transit and the quadrant and the Astronomer Royal *had* to employ an assistant, he also every right to regard their labours (i.e. recording the results) as part of his own work.

It was also discovered that the RGO does not have a copy of the Bayer Star Atlas - surprising for an Observatory of such stature but explicable if Bradley already possessed his own personal copy. Having worked on it so long he might not, therefore, have regarded it as an essential piece of Observatory equipment. The Observatory does, however, possess a copy of the text of *Uranometria* dated 1654, published in Augsburg. The nearest date for Star Map publications are 1648 and 1655 but neither, as far as known, depicted the Cherub at the base of the publisher's scroll.

All the clues unearthed seemed to point to James Bradley *vis*:

1. There was no-one else with similar handwriting, nor any other observer at Greenwich at that time able to perform such accurate work!
2. Bradley not only had access to suitable instruments but was in a superb position to use them:
3. Bradley was expert in the skills needed to improve the existing instruments to the standard needed to make such observations, and actually did so: no other candidates appear to exist who did the same thing.
4. The watermarks on the handwritten pages were authentic, clearly indicated someone in official service and coinciding with Bradley's employment at Greenwich Observatory.
5. The known enthusiasm of Bradley for this sort of work agreed exactly with what had actually taken place.
6. Bradley used to be Professor of Astronomy at Oxford, as was Nathanial Bliss subsequently, and who is referred to in the text in connection with the Bevis Atlas.
7. Flamsteed, the First Astronomer Royal, also used, as the basis for his major catalogue, the star maps - alone - from *Uranometria*, and in the same manner and for the same purposes as our unknown observer had done.
8. The year 1749, which marked the close of these observations, was an extremely significant date to James Bradley. It coincided with the receipt of a grant from George II which opened the door to great new opportunities which, thereafter, must have dominated his attention.

Against this may be set the contents of the introductory notes. For example, are these the sort of notes that would be written by James Bradley, then at the age of about 54 and who had been Astronomer Royal for five years? Would such an eminent astronomer have written text such as "fancyed I had got something worth communicating to the public" and would Bliss, who regularly visited Greenwich, have waited until Bradley had worked on 11 of the plates before telling him about Bevis' work? Furthermore, if the author, in his second paragraph, was referring to Flamsteeds' *Historia Coelestis* as being published in 1690, he is wrong. Bradley would never have made such an elementary mistake. The "spurious edition" of Flamsteed's observations was published, much against his will, in 1712. Flamsteed's own three-volume catalogue appeared posthumously in 1725.

All these points are open to interpretation in other ways. Indeed, the work might be that of some well-educated amateur unknown to us at present, though the Royal watermark on the paper, indicating someone in Government service, makes it unlikely that such an amateur could meet this criterion as well. Indeed, the juxtaposition of such circumstantial evidence pointing to James Bradley is startling.

This is how the position rests at present but we are continuing our researches for this is a fascinating subject and who can tell in which direction it may lead?

Conclusion

It is abundantly clear that we have an important find and, as a consequence, the Council of our Society has agreed that all these pages i.e. those from the original print of Bayer's *Uranometria* augmented and extended by pages of additional observations made, as far as it appears at present, by James Bradley, the third Astronomer Royal, should be made available in a facsimile form.

To carry this out the Society is making arrangements for these large-scale maps and writings to be reproduced, using the photographic plates carefully prepared in the initial stages of our investigations.

The facsimile will appear as a limited edition of 500 copies only. Two versions will be available, one bound in Buckram (£160) and the other in calf vellum (£250). They will be identical in all respects except for the binding. Members interested in securing copies (there will probably be a special pre-publication price) are asked to make their wishes known to the Executive Secretary at HQ as soon as possible.

Currently only a few good copies of the first edition of *Uranometria* are on the market. Their cost averages about £4,500 each though one auctioned in 1980 reached £6,500. These consist solely of the star maps with Latin wording on the reverse of each. Later editions are slightly cheaper, with one in good condition costing about £2,500. These prices, of course, disregard the fact that our own facsimile, although with a slightly damaged frontispiece, is unique insofar as the size of the work, alone, has been more than doubled by the inclusion of page after page of additional observations. The enormous labour that went into making these observations underlines the outstanding character of the book which the Society is to reproduce.

Acknowledgements

Our grateful thanks are due to Janet Dudley (Archivist) and Adam Perkins (Supervisor of the Laurie Cataloguing Project) both at Royal Greenwich Observatory, Herstmonceux, for reading the manuscript and providing numerous helpful suggestions, photographs and support, and to Carole Stott at the Old Royal Observatory for providing additional illustrations.

THE STORY CONTINUES ...

Owing to the intrinsic interest of this volume and the valuable nature of the research being undertaken, the authors are making further enquiries into the circle of friends that surrounded James Bradley, and other luminaries of the astronomical science in the 18th century. The first fruits from this will take the form of a second article that will appear in the near future, entitled "The Quest for Nathaniel Bliss."

SATELLITE TRACKING WITH GEODSS

By Joel Powell

A new US Air Force optical system recently became operational to track and record satellites, replacing the cumbersome Baker-Nunn telescopic cameras in use for more than 25 years. Geodss — Ground-based Electro Optical Deep Space Surveillance — uses image-enhancing TV cameras to track spacecraft orbiting between 800 and 36,000 km.

The Geodss System

The complete Geodss network is expected to be fully operational by January 1987 with five observatories around the world: White Sands, New Mexico; Mount Haleakala (Maui), Hawaii; Taegu, South Korea; Diego Garcia Island in the Indian Ocean and (provisionally) in Portugal.

The system sweeps the skies watching for hostile satellites and monitoring orbital spacings to prevent collisions. Its data also help to forecast when and where space vehicles decaying from orbit will fall.

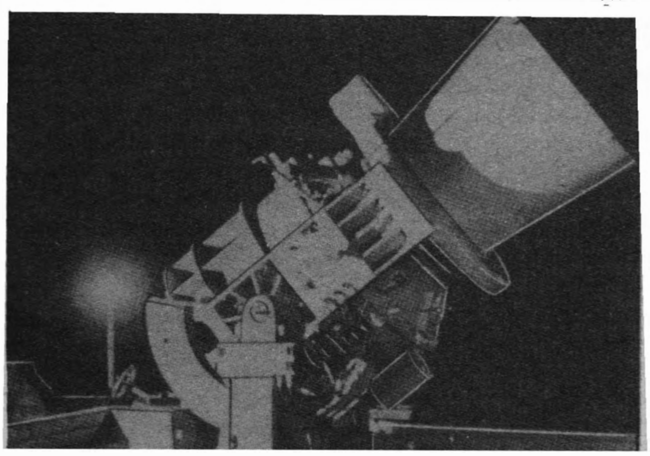
Each installation has two primary 1 m "deep space" telescopes and a separate 40 cm auxilliary telescope to track fast-moving satellites in low Earth orbit. The main telescopes are Ritchey-Chretien reflectors with focal lengths of 218 cm and 2.1° fields of view, each carrying a 36 cm radiometer to measure light variations of the target satellites.

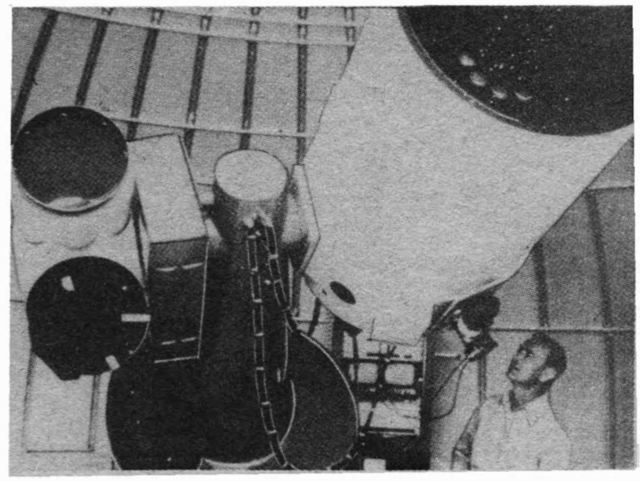
The auxilliary telescopes are Schmidt cameras with folded optic 6° fields of view and focal lengths of 76 cm. They can move from one observation to another in only one second with a pointing accuracy of 1.5 arc seconds and a maximum slew rate of 15° per second.

At the heart of the Itek low-light vidicon tubes at the focal plane of each telescope is a tiny device known as a silicon intensified target (SIT). This electronically amplifies light to allow observations of objects as faint as magnitude 16 (the equivalent of a football in geostationary orbit). Charge-Coupled Device image enhancement systems will be fitted later to upgrade the system.

Four PDP II/70 computers carry out programmed tracking work and perform data processing at each site. Each telescope is controlled from two dual position consoles with data relayed to the Space Defence Operations Center (Spadoc) of the Air Force Space Command located at NORAD headquarters in Colorado.

A UK Hewitt Camera, an older film camera for satellite tracking. *Univ. of Aston*





The primary (right) and secondary telescopes of the Experimental Test Site at White Sands Missile Range, built to develop Geodss tracking procedures. *USAF*

Spacetrack

The US Department of Defense operates 'Spacetrack,' a global network of optical, radar and radio tracking stations collectively known as the Space Detection and Tracking System (Spadats). Geodss is a replacement for the 0.5 m Baker-Nunn tracking cameras which were developed and operated for the US Air Force in the 1950's by the Smithsonian Astrophysical Observatory.

When Geodss became operational, four of the 12 Baker-Nunn sites from the 1960's remained: Mount John, New Zealand; Sand Island, the Pacific; Edwards AFB, California and one in Italy. The conventional photographic film used by Baker-Nunn required 90 minutes of processing and analysis for each observation. Geodss performs its tasks 100 times faster and can detect objects 2 magnitudes fainter. Until all five sites are fully operational, three of these cameras will remain in service. The US Air Force also operates laser tracking stations and a classified network of cameras for close-up photography of satellites.

The first Baker-Nunn made its initial satellite observation even before it was shipped to the observatory site at Cloudcroft in New Mexico. When Sputnik 1 was launched on 4 October 1957, the camera was hastily set up in the yard of the assembly plant in Pasadena, California to photograph it.

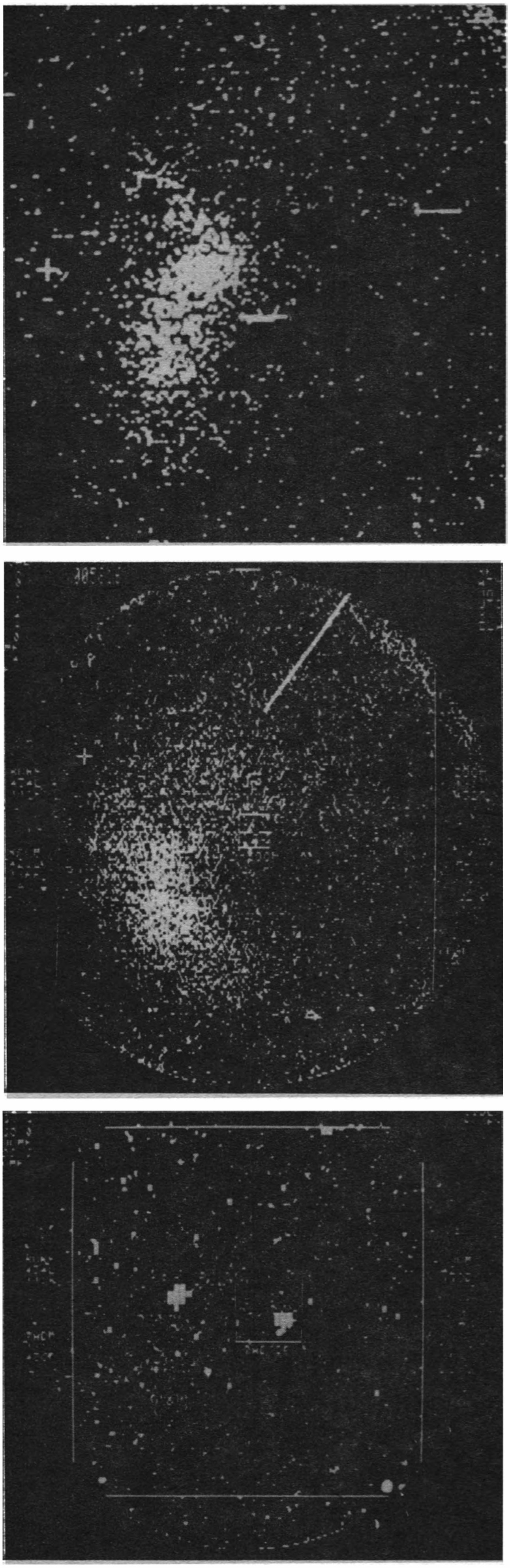
Spacetrack makes extensive use of radar. All objects in deep space are followed by three large radars at Millstone Hill, Massachusetts; Kwajalein Atoll, the Pacific and in Turkey. Objects in low orbit are followed by the giant AN/FPS 85 phased array radar at Eglin AFB in Florida. Worldwide, seven USAF radars are routinely used for satellite tracking.

The US Navy operates the Space Surveillance System for Spacetrack, consisting of a "fence" of radio beams projected across America by three powerful transmitters. Space objects betray their presence by interrupting the radio beam, which is detected by six separate receiving stations in the continental US.

The Soviets operate their own tracking system, including radars and a network of at least two dozen telescopic cameras. Based upon NAFA aerial cameras, the telescopes are roughly comparable to the Baker-Nunn.

Development

In the early 1970's the USAF recognised the need to replace Baker-Nunn with a faster system that could keep



Three examples of Geodss at work. *Top:* the system has picked up two satellites. The operator would then mark the ends of the tracks and they would be compared to known satellites; the central streak is a Fltsatcom satellite in geostationary orbit. This MTI mode keeps the telescope pointed at the area for longer than normal, allowing faint images to be stored and superimposed. *Centre:* a satellite 8000 km up leaves a long track as frames are collected. The small square marked in the centré can be enlarged 12 times to become the large square at *bottom*. The object at the centre is now in the radiometer's field of view (the small square) to register its light pattern to see if it is a satellite proper or just tumbling debris. The clump to the left is a star.

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pace with the increasing number of space objects. It is currently estimated that there will be 1,500 objects in deep space by 1985, compared with only about 500 in 1978.

In order to develop the advanced system, the Lincoln Laboratory of the Massachusetts Institute of Technology established an Experimental Test Site at White Sands in New Mexico. There they tested an 86 cm primary and a 36 cm secondary to practise television tracking and to develop associated computer software.

ETS remains in use to complement Geodss operations. An important observation was made in April 1983 when it recorded the reversal of direction of the Inertial Upper Stage second stage during the burn to boost TDRS 1 towards geostationary orbit.

In February 1980 TRW, the system's main contractors, set up two Geodss telescopes for the first time at their Newbury Park, California test site for evaluation under a variety of observing conditions. They were later shipped to the South Korean site for installation and the first operational site was completed at White Sands in 1982.

Procedures

Every evening the Geodss computers receive a pre-planned observing schedule from Spadoc. Observations begin with preliminary scans of the target area so that the computer can identify and delete the background stars - elmination of background clutter is the key to speed and accuracy.

For easy recognition, satellites are displayed as streaks on the video monitor as the telescopes are guided on the background stars to cancel out the stellar motion caused by the Earth's rotation. In the semi-Automatic Moving Target Indicator mode, the operator "marks" the coordinates of the streak and the computer will calculate the position and velocity of the target.

For faint objects, an "electronic zoom" feature can reduce the field of view by 12 times to cut down the number of stars that the computer must process to search for a dim object.

The second major operating mode is Space Object Identification in which the electronic zoom is used to centre the target in the radiometer's field of view. This information can then distinguish between steady or tumbling payloads, spent rocket bodies or debris.

When a satellite has manoeuvred and does not appear at its expected coordinates, the Maneuver Query Mode is used to reaquire the target and to calculate the new orbit. A precision Position Measurement Mode is used to update the orbital parameters of spacecraft for the NORAD Resident Space Object Catalogue, the registry of all orbiting objects.

Each Geodss observatory works at the pre-planned tracking schedule each night as long as the sky is dark enough. Tracking in real-time locates newly-launched or searches for disabled craft such as the Westar 6 and Palapa B-2 communications satellites that went astray after leaving the Space Shuttle in February 1984.

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Both Fellows and Members may now purchase high-quality certificates suitable for framing. These are 29.5 x 41.5 cm in size, printed in three colours and with the member's name hand-inscribed. They are available for only £5 ($8) post free.

When ordering, please indicate membership grade and allow six weeks for delivery. Provision for ordering these certificates also appears on the 1985 subscription renewal form.

BACK ISSUES

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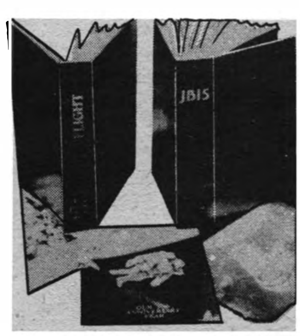
BINDERS

The ideal way of keeping your magazines in perfect condition. *Spaceflight* binders carry *BLUE* covers, those for *JBIS* are *GREEN*. Gold lettering on the spine identifies the magazine, volume number and year. Cost: £5 ($8 abroad) each. Note: *JBIS* binders fit post-1976 volumes.



SALYUT MISSION REPORT

By Neville Kidger

Continued from the December 1984 issue

The record-breaking flight of cosmonauts Kizim, Solovyov and Atkov is brought to a close. Possible missions to Salyut 7 during 1985 were discussed on pp.81-82 of February's *Spaceflight.*

Cosmonauts Kizim (right) and Solovyov (left) trained together as backups for the French Salyut mission in 1983. Frenchman Patrick Baudry (centre) will fly aboard the US Shuttle this spring. *Novosti*

Progress 23 in Space

Progress 23 was launched at 0628 (all times GMT) on 14 August 1984 and docked at 0811 two days later with Salyut 7's rear unit. The craft delivered various cargoes for the use of the Mayaks (cosmonauts Kizim, Solovyov and Atkov), as well as propellant for the repaired Combined Engine Installation (ODU) of the station. The Mayaks opened the hatches to the cargo ship at 1500 on the 14th and unpacked their personal mail.

The Mayaks were performing intensive Earth studies during this same period and, on 17 August, the Progress engine was used to modify their orbit. On 20 August the station was reported to be in an orbit with parameters of: 351 x 387 km; period 91.7 mins. Over the next few days the cosmonauts refuelled the ODU, replaced life-support system items and continued their Earth observation programme.

The cosmonauts made emergency repairs on an electrophoresis separation unit to save the 'Genom' experiment, cannibalising a similar, though less powerful, unit for spare parts in less than an hour. 'Genom' was intended to separate some 700 DNA samples, the procedure being recorded on UV film.

On 26 August, at 1613, Progress was undocked after one of the shortest flights of that series; it was destructively deorbited at 0128 on 28 August over the Pacific.

Observing Earth

During late August and early September, the Mayaks participated in two Earth observation experiments which the USSR was conducting with the help of other countries of the Intercosmos organisation. In the first, called 'Black Sea,' they took photographs of the inland sea to complement data being gathered by the Meteor-Priroda satellite and the oceanographic Cosmos 1500 satellite. On the Sea itself information was collected by the research ships *Mikhail Lomonosov* and *Professor Kolesnikov* with flying laboratories and automatic buoys. The experiment, still in progress, seeks to establish baseline data for the study of ocean areas. As well as photography, the cosmonauts used optical and infrared spectrometers.

In the Gunesh (Sun)-84 experiment, the cosmonauts were required to take photographs and spectrographic data of a special test site in the region of Sheki and Zakatoly Rayons in Azerbaijan, as well as areas around the Mingechaur storage lake. Researchers were also collecting data from ground-based mobile laboratories, helicopters flying 200 m high and aircraft at 4 km.

In addition to this type of work, the cosmonauts continued their physical exercises and medical experiments under the guidance of Dr. Oleg Atkov.

During the night of 6-7 September the three cosmonauts surpassed the 211-day space duration record established only two years earlier on Salyut 7 by the Elbrusy crew of Berezovoi and Lebedev. For the new stay to become an offical record, however, the crew needed to be aloft for 10% longer.

In a press conference for the Soviet media to mark the passing of the record, journalists were told that controllers and scientists agreed that a crew of three was the optimum for a space crew for efficiency. They were told that the flight had 'entered its final stages.' (At a press conference in the West, cosmonaut Nikolai Rukavishnikov reportedly said that the visit of the Soyuz T-12 crew had caused the Mayaks psychological problems because it had upset their normal working rhythm).

Physically, the cosmonauts had lost an average of 15% of the volume of their tibias because of calcium leaching from the bones, although specialists pointed out that this was about normal for long space missions. The cosmonauts showed little variation in their weights - one had lost, another had gained slightly and the other had remained stable.

Lilac in Space

By 7 September the Mayaks had begun astronomical observations with an X-ray spectrometer called Sirene (Lilac), developed jointly with France. The telescope was mounted in Salyut's depressurised adapter module and connected to a control panel in the working module. The instrument had been delivered by Progress 23.

Up to 21 September the cosmonauts conducted 46 observing sessions, looking at 10 targets. Objectives included an attempt to determine the temperature profile of the Cygnus X-1 black hole accretion disc (where matter from a large blue star is being pulled into the black hole). X-ray pulsars and the Crab Nebula were also observed.

Facing page: the three record-breaking cosmonauts (from top Solovyov, Atkov and Kizim with Svetlana Savitskaya aboard Salyut 7.

Returning to Earth

In the last ten days of September the cosmonauts began to end their experiments in preparation for their return to Earth. In a radio broadcast from the station, Kizim said that the crew were to return before the first snows fell. A Soviet report said that the crew were being kept busy in an effort to avoid 'psychological idleness' and they used the Chibis suit to prepare their bodies for the return. Final tests in the acceleration series were conducted to test the dynamics of the station.

On 1 October the Soviets said that the cosmonauts were to return the next day. The cosmonauts had spent part of the day reactivating Soyuz T-11's systems and transferring material into the Soyuz descent cabin.

The Mayaks were awakened at 2200 on 1 October (0200 2 October Moscow Time). They crossed into T-11, closed the hatches and had dinner. They then put on their pressure suits and at about 0630 undocked from the Salyut's front unit. Following retrofire, separation of the descent cabin and the instrument module took place at 0924:54, before striking the dense layers of the atmosphere. Touchdown occurred at 0957 some 145 km south-east of the town of Dzhezkazgan.

The cosmonauts were soon lifted from the module into special lounge chairs where TV pictures showed them to be looking very tired. They were then taken to a medical tent erected at the site. Atkov later said that his first sensation after the landing was the smell of field wormwood and the 'dense and tasty' air. The mission had lasted just a few hours under 237 days.

Readaptation to Earth

The cosmonauts were flown to the Kosmanavt Hotel at the Baikonur Cosmodrome the same day to undergo a series of thorough medical tests to study their readaptation to Earth's gravity. A Soviet report credited their good humour to the 150 communications sessions held with the Psychological Support Group at the Flight Control Centre during the flight.

TV pictures showed the cosmonauts during their medical tests. Kizim had to be supported gently as he walked rather uncertainly along a corridor; Atkov hugged a nurse, his face covered in electrodes. The USSR's top cardiologists were present; one described the condition of the cosmonauts as being similar to that experienced by patients after long stays in bed, only rather worse - they used the phrase 'state of medium severity.'

It was noted that, although the cosmonauts looked weak, they would soon be walking unsupported and their blood volume would reach pre-flight levels. The flatfootedness and spells of occasional dizziness would soon disappear.

On 4 October they were interviewed briefly by selected journalists and allowed to have their first walks outside. By 5 October Kizim was standing more steadily. Watching the cosmonauts on a stroll, Vladimir Kovalenok (a veteran of two long space flights) noted that the Mayaks seemed 'frail at the moment.' He speculated that the various techniques used to minimise the effects of weightlessness may need to be more 'daring' for future flights. Despite their condition, the cosmonauts seemed to be ahead of schedule in readapting.

Immediately after landing Atkov had been measured as some 5-6 cm taller than before the flight because of the expansion of his spine. The others joked that their clothes seemed to have shrunk but gravity soon reduced their heights to pre-flight levels.

The crew expanded their exercise routines by swimming and increasingly lengthy walks; the exercises were tailored for each man with regard to his physical structure (Solovyov, for example, is tall and more prone to orthostatic changes).

In an interview with Radio Moscow's Home Service, the Director of the medical group at Baikonur told a reporter that it was feasible to think of cosmonauts walking away from their spacecraft after a one-year flight if artificial gravity were used. 'I think that this is our near future,' he said.

An alternative view was expressed by Rena Kuznetsova who wrote that such measures as artificial gravity, which greatly complicates the design of spacecraft, may not be necessary if correct medical preparations and exercises are followed. It was noted that the 237-day flight was long enough to reach Mars with the current level of technology.

The Mayaks completed their post-flight check-ups on Sunday, 21 October and returned to the Brezhnev Zvyodznyy Gorodok the next day.

The Press Conference

On 25 October the Mayaks gave their post-flight press conference in Moscow. It had been noted that, throughout the flight, they had conducted over 500 experiments involving about 2,100 radio commands beamed at the station, with 250 TV sessions and 1,800 radio messages.

Kizim noted they worked in blocks during their scientific programme. In tandem with their medical work, they spent one to two weeks at a stretch on a particular scientific discipline. The normal working day lasted for 8½ hours, with 6 hours devoted to experiments and the rest to preparation. The distribution of the workload was left to the crew to decide in accordance with their wishes.

Vladimir Solovyov described the six EVAs, totalling 22 hours and 50 minutes, which the cosmonauts had undertaken to repair Salyut's main propulsion unit. He also noted they had obtained some 5,500 Earth photographs for some 800 organisations to use throughout the USSR for a variety of studies.

However, the presence of a doctor in the crew was highlighted by the Soviet media throughout the flight. Atkov told the journalists that his studies concentrated on the cardio-vascular system and that he had had a large number of instruments at his disposal. These included vector cardiograms, reographs, a portable echocardiograph and ultrasonic diagnostic systems, which made it possible to look into the heart, blood vessels and other internal organs.

Blood samples, taken on the 100th and 200th days, were being used in the study of the levels of calcium, phospherous and magnesium. Other experiments studied the rate of carbohydrate exchange, with a functional probe containing glucose, and the exchange of calcium in cell membranes. It was noted that the exchange does not occur in weightlessness and this could lead to disturbances in cell functions.

According to an analysis of the 2.5 - 3 hours of daily exercises, Dr. A. Nicogossian of NASA said that they and other measures were of only some 60-70% efficiency in preventing serious effects. He was quoted by the US press as saying that the level would need to be increased when lengthy flights began on the US Space Station in the 1990's.

As if to answer this observation, Atkov told the press conference that 'The fact that a little over three weeks after returning... we are before you in good health... is probably the best confirmation (of the regimen of preventative measures).'

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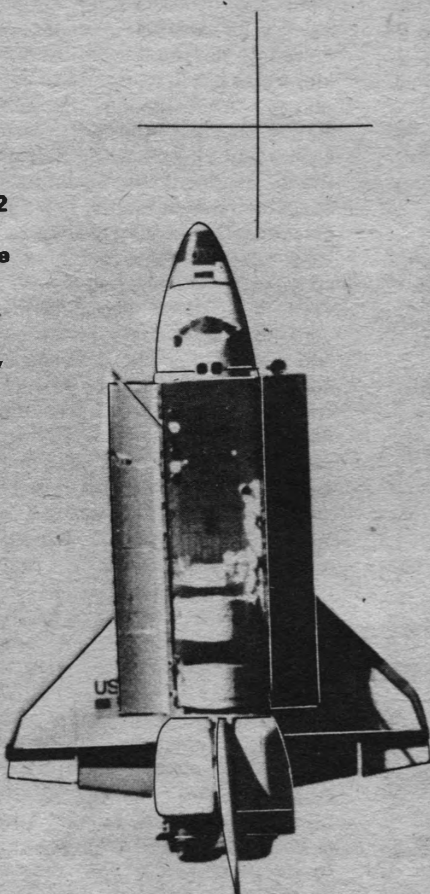
SOCIETY BOOKS

PROJECT DAEDALUS

The publication of the Project Daedalus Final Report marked the end of years of painstaking work by a group of BIS pioneers. The BIS received congratulations from around the world for its far-sighted project: designing a probe for man's first crossing of interstellar space.

The Final Report Report contains 24 papers spread over 192 large-format (A4) pages, summarising the four year study. The papers cover the overall spacecraft design, mission profile, computer systems, navigation, experiments and our knowledge of nearby stellar systems, some of them possibly with planets.

"Daedalus" is acknowledged as a milestone in the the development of advanced astronautics. Copies of the Report cost just £7.00 ($11.00) post free.



THE EAGLE HAS WINGS

An exciting progression of space achievements in the years following the Second World War led to Man's first landing on the Moon in 1969. Rockets for probing the upper atmosphere evolved into the space launchers we know today. Vanguard, Explorer, Atlas, Titan, Mercury, Gemini, Apollo – a succession of names to conjure up memories of the 50's and 60's when man was taking his first tentative steps into outer space.

The Eagle Has Wings tells the story of the major US Space projects from 1945 to the watershed year of 1975, when the Apollo missions came to an end and the first wave of interplanetary exploration gave way to the more sophisticated probes of today. Written by *Spaceflight* managing editor Andrew Wilson, it is packed with information and photographs. It runs to no less than 144 large-format pages and can be obtained for the low price of £7 ($11.00) post free.

HIGH ROAD TO THE MOON

Every member ought to own a copy of this unique 120 page publication which records many of the Society's early ideas and discussions on Lunar exploration in the visionary drawings and illustrations of the late R. A. Smith.

Pictures and drawings detail plans for orbital rockets, space probes and ships to take men to the Moon and Lunar exploration. Some are familiar illustrations used in books of the time: others have not been published before.

Bob Parkinson has brought these pictures together with a commentary which tells how the pioneers imagined things would be and how they actually were. It goes beyond the present, for man's involvement with the Moon is not yet finished. Using the Smith pictures as a background, Dr. Parkinson looks at the possible future for the Moon and how it might be brought about.

Price: £6.00 ($9 .00) post free.

All of the books are available from: The British Interplanetary Society, 27/29 South Lambeth Rd., London SW8 1SZ, England

THE BRITISH INTERPLANETARY SOCIETY

ASTRONAUTICS AT LAUSANNE

The report on the 35th IAF Congress in Lausanne, Switzerland in October 1984 is continued with summaries of the Technical Sessions.

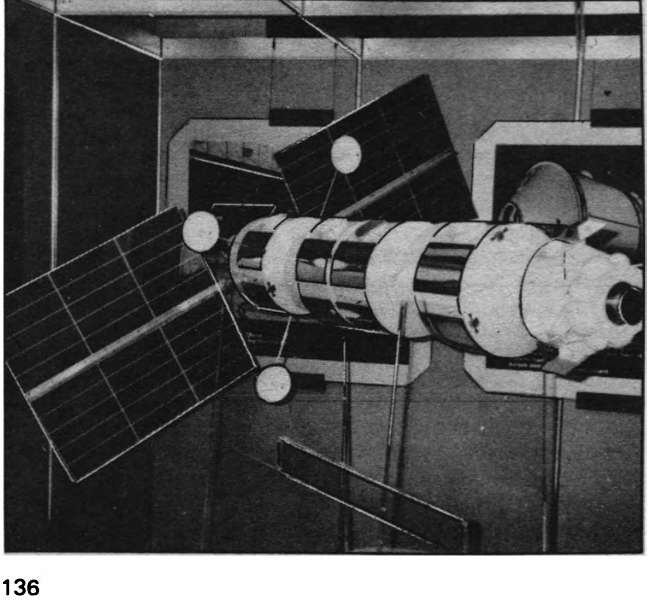
COMMERCIALIZATION OF SPACE ACTITIVITIES

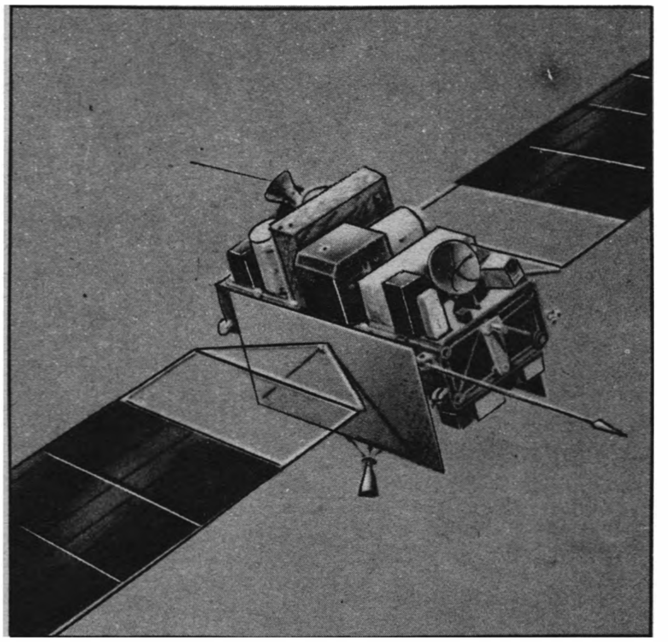
The "Commercialization of Space Activities" session of the 14th International Space Symposium on Space Economics and Benefits introduced the subject of commercialisation by discussing the various tools available to government to influence private sector investment decisions. Joint Endeavor Agreements and R&D Limited Partnerships were pointed to as being of significant importance. The former was discussed in detail, emphasising the point that, since NASA must negotiate with the private sector, they should plan and evaluate private sector business ventures in order to establish an informed negotiations stance. The role of RDLPs was mentioned and then discussed briefly by David Thompson (Orbital Sciences Corp.). This was the mechanism used by OSC to attract an appreciable portion of the funding necessary for its development of a new generation of Shuttle-compatible upper stages based upon space-proven technologies and a modular design approach.

Ike Gilliam, recently appointed to head the NASA commercilaisation activites, introduced NASA's approach to the commercialisation of space (the paper was written by P. Templeton of NASA). He indicated that there are three specific types of commercial space ventures NASA will consider: new commercial high-tech ventures; new commercial applications of existing space technology; commercial ventures resulting from the transfer of existing space programmes to the private sector. NASA's commercialisation policy will be governed by the following principals:

1. government should establish new links with the private sector,
2. government should not be the overall judge of feasibility or impede private efforts,
3. encourage commercial activity that can be performed more efficiently by the private sector,
4. government should invest in high leverage technology,
5. government will consider a significant contribution to a private sector initiative if there is considerable private sector capital at risk and there is significant potential benefit for the Nation.

The Columbus space station concept could provide Europe with extensive experience in orbital operations.





The European retrievable payload carrier, Eureca, will encourage commercial space activities. *ESA*

NASA has established a Commercial Space Office under the leadership of Mr. Gilliam to serve as the focal point in the Agency for commercial endeavours.

George Hazelrigg (National Science Foundation) reviewed the steps that led to a successful commercialisation of communication satellite technology. He developed models for commercialisation and used the expendable launch vehicles (ELVs) as a case study. He concluded that there is a need to recognise that the development of a scientific and technical infrastructure for space commercialisation is an appropriate role for NASA. The aerospace community needs to focus on the creation of this infrastructure rather than Federal policy as its approach to space commercialisation.

Klaus Iserland (Arianespace) stated that "launching an unmanned spacecraft with a manned vehicle is pure luxury" and wished to see launch vehicle competition on an actual cost basis without subsidies. Arianespace pricing is based on the concept that fixed costs are covered by European launches. Additional production (above three/year) is at risk and can be sold in foreign markets using prices based upon marginal costs. Iserland stated that Shuttle price places a cap on Ariane price and he would like to see prices rise. Nonrecurring costs are written-off as in the US. It was pointed out that international exchange rates are a major factor in the Ariane price relative to the Shuttle price.

Peter Kleber (DFVLR) concluded that for the time being there exists considerable ignorance about the possibilities of industrial applications of space. To overcome this a long-term process is required.

John Logsdon (George Washington University) raised a number of questions: Is it really 'harvest time' for large scale payoffs from space? Or is substantially more seeding, fertilising, cultivation and weeding out required before the harvest is ready? He pointed out that although there has been considerable progress, particularly with the removal of barriers, much remains to be accomplished. He presented a number of interesting observations including the problem of how commercialisation is more basic than setting up a new office or pursuing a set of initiatives - NASA has 26 years of experience in doing business in a particular fashion, one that has been largely driven by internal technical objectives. There have been no significant new investments in space made this year and none of the private ELV firms or new upper stage developers have a single customer yet, although all claim to be close to an initial agreement.

A realistic assessment has to conclude that the political and policy attention now being given to space commercialisation in

the US is out of proportion to its short-to-mid-term economic significance.

DR. JOEL GREENBERG

MOBILE COMMUNICATIONS

Depite the fact that most satellite communications systems to date have been developed in the fixed telecommunications service, the most natural applications of satellites, and those that get practically no competition from terrestrial means, are the broadcast and mobile services. The geometric advantages place satellites in a class by themselves for the provision of wideband, wide-area telecommunications to unspecified or to mobile locations. The use of satellites for maritime service, started a number of years ago, has acquired substantial world-wide momentum and, at last, is beginning towards expanding to the aeronautical services.

Currently, and this was the main theme of the "Mobile" sessions, there is a distinct movement towards the use of satellites for communication with ground mobile terminals. Motor vehicles and trains all have substantial communication requirements that are not being met by existing systems. Even the rapidly developing cellular mobile telephone systems will not supply services to anything but metropolitan areas. The papers given clearly showed the technical problem in its essentials. The vehicle terminals must be cheap, therefore, the antennae must be non-directive and the use of relatively low frequencies (the UHF band) is mandatory. Because of the very low received antenna gain, high EIRPs are required in the satellite and they are achievable only with multiple spot beam antennae. The use of such antennae has the further advantage that it permits frequency reuse. The first systems to be developed in the US and Canada will use only three or four spot beams, but it is clear that ultimate operational systems will have many spot beams, perhaps in the hundreds, to achieve high levels of performance and to cover entire North America. The technological challenge will, of course, be to develop cheap antennae and transmitter-receivers for use in the vehicle and this will be facilitated by the use of large and very sophisticated multiple beam phased array antennae in the spacecraft.

The papers given highlighted not only the technological problems of the mobile service but, to a substantial extent, some of the institutional problems. In the US and Canada, many agencies will be involved in a multi-faceted project. The Canadian Department of Telecommunications, the US Federal Communications Commission, NASA, Telesat of Canada and, as yet unidentified entrepreneurial activities, are in the process of cooperating in the early system development, technological developments and planning for the ultimate operational system. It is envisaged that, by the end of the decade, commercial ground mobile satellite systems will be serving the North American market.

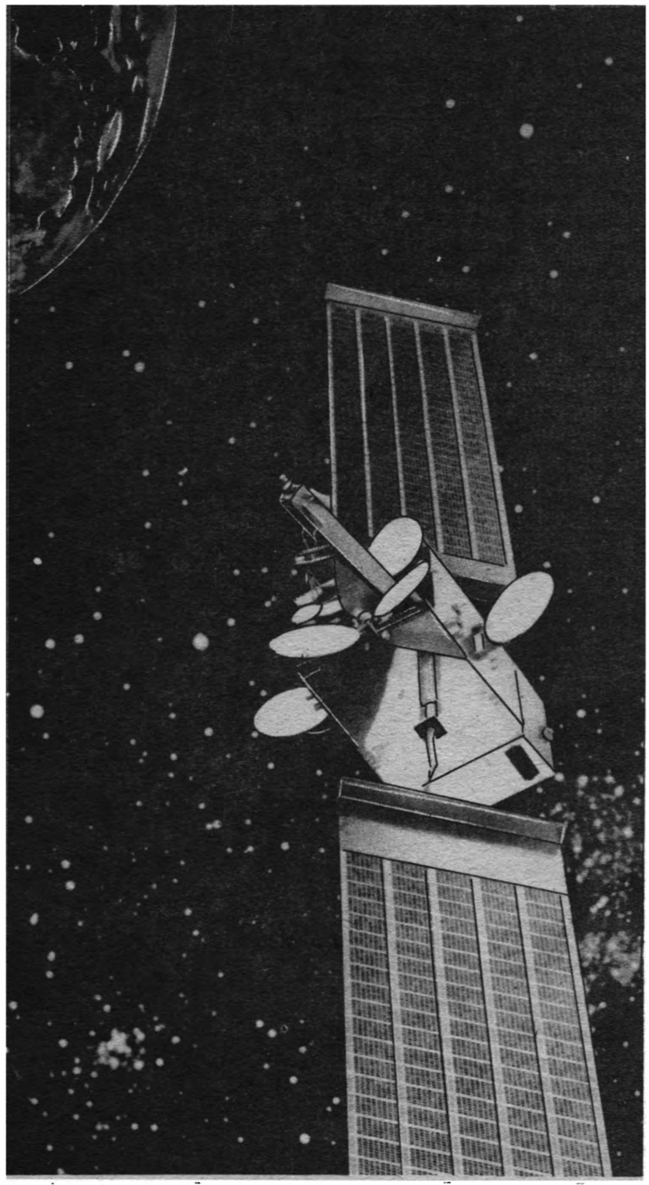
WILBUR PRITCHARD

MICROWAVE SENSORS

The session on Microwave Sensors was devoted to two critical areas:

1. the design of space-borne altimeters;
2. the state-of-the-art in the area of deployable antennae (design and performance) for SAR and scatterometers.

The first paper "Development of microwave altimeters in Japan" by Y. Miyachi *et al*, reviewed the design of an altimeter to be flown in the late 1980's (not yet part of any approved mission). The presented design, although heavily relying on the Seasat altimeter in terms of return signal model, concept approach (i.e. full deramp technique), leads to an improved accuracy by using a more sophisticated tracking algorithm. In fact, the onboard bit-slice microprocessor does not restrict the selection of the tracking algorithm and complete maximum likelihood or minimum mean square error estimators are possible.

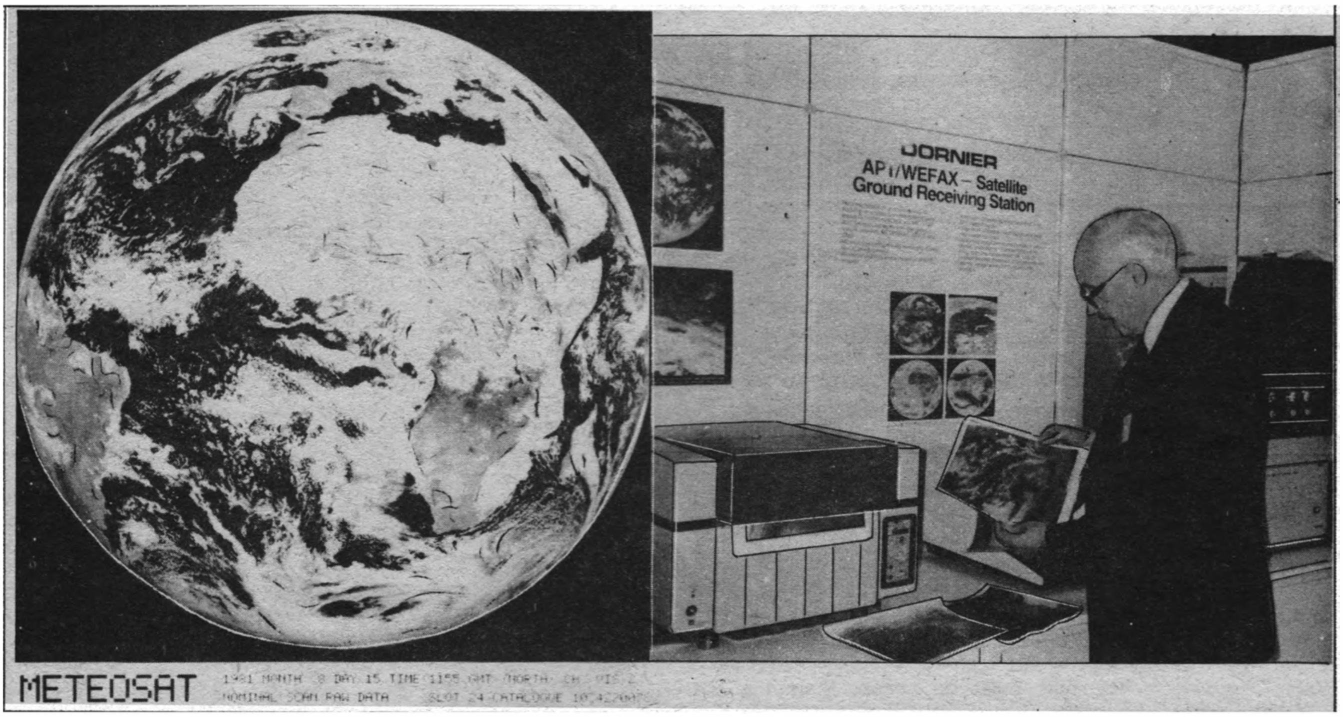


Europe's Olympus satellite, being built by British Aerospace, will allow the use of smaller receiving antenna because of its power. *ESA*

The second paper on altimetry, "The French Payload on-board Topex" by J.P. Aguttes *et al*, focused on a possible package, 'Poseidon,' to be flown in 1989 on the US Topex as part of a cooperative programme between NASA and CNES. The package consists of two main sections: an altimeter and a localisation system ('Doris'). The altimeter itself is, again, an improved version of that flown on Seasat. The improvement arises from a refined return echo model (still to be selected) and therefore a more accurate maximum likelihood estimator. Since the mission is heavily ocean topography orientated, the altimeter is supported by a localisation system for accurate orbit restitution. It relies on one-way doppler measurements between ground beacons and the satellite receiver. Doppler measurements are made simultaneously on two frequencies: 401.25 and 2036.25 MHz. All the beacons are continuously transmitting simultaneously on the same frequencies.

The system is such that, at any given time, the doppler frequency is known (program loading from ground). The discussion centred on the factors limiting overall performance (e.g. ultra-stable oscillator). Simulation results were presented since the breadboards are still under design and/or manufacture.

The remainder of the session showed that the antennae do constitute an essential part of any synthetic aperture radar (SAR) design. The multiple trade-offs that lead to the selection of a planar antenna (14 x 2 m) for the Radarsat programme were present ("The Radarsat SAR multi-beam antenna" by L. Martins-Camelo *et al*). In particular, the requirement for switchability among four shaped beams and the high power of



Left: an example of a Meteosat image in visible wavelengths. *Right:* the Executive Secretary, L.J. Carter, inspects a Meteosat 2 image received at the Congress. *ESA*

transmitter operations are major design constraints that strongly impact on the antenna complexity.

The selection of the planar array is based mainly on its simpler deployment mechanism, despite the requirement for deployable electrical connections. This technology has been used with the Seasat and European ERS-1 satellites.

"The SAR and scatterometer antennae on ERS-1" by G. Graf concluded the session. Several technologies are used:

1. carbon fibre reinforced plastics (CFRP) for the 10 x 1 m SAR antennae;
2. aluminium slotted waveguides for the scatterometer antenna.

Apart from reviewing the missions and antenna design requirements, two major difficulties encountered during technology development activities were emphasised: the metallisation of CFRP waveguides and the multipaction effect. The metallisation process is now based on an indirect technique: the mandrel is metallised prior to CFRP manufacturing and a specially developed surface treatment ensures appropriate bonding between the metal layer and CFRP. A recent test series has led to the successful prequalification of representative waveguides. A total of 10,000 thermal cycles was run, representing two years' orbit life.

Multipaction is a resonant electron discharge effect that appears in vacuum and high RF fields. It takes energy out of the transmitted signal and generates noise. Physically, it can deteriorate and destroy the surfaces. This particular difficulty is not solved yet, despite many efforts in various laboratories.

As a whole, the microwave sensors session demonstrated a high level of activity throughout the world. In most cases, the design is completed or near completion, breadboards have been tested and technologies developed for missions to be flown in the late 1980's.

J.P. GUIGNARD

EARTH OBSERVATION

The seven papers presented on 'Optical Sensors for Earth Observations' covered the current and near-term future state-of-the-art in optical imaging of land and sea surfaces. Examples were given of different instruments using the three recognised scanning techniques: swishbroom, pushbroom and snap-shot; as well as almost the complete range of detection principles available: film, discrete detectors, linear and metric charged coupled devices and electronic imaging tube devices.

Four papers described the in-orbit performance of already-orbited sensors; the MBB MOMS, the DFVLR/ESA Metric Camera, the NASDA ETS-3 Vidicon Camera and the NASA Thematic Mapper. The Landsat 4/Thematic Mapper paper was particularly significant as it reported on the results of a meticulous analysis of all dynamic disturbances distorting the raw image quality and the subsequent processing necessary to recover the geometric quality inherent to the sensor.

The report on the Along Track Scanning Radiometer highlighted the two most significant aspects of this instrument, which is being developed by the Rutherford Appleton Laboratories for ESA's ERS-1 satellite; namely the potential improvement in sea-surface temperature measurement to be obtained and the development of the Stirling cycle cooler to be employed for the necessary detector cooling.

Finally, the presentation of an imaging spectrometer concept utilising a theoretically non-polarising grating mount combined with a matrix CCD detector offers a number of interesting ideas for future consideration. Although conceived by Aerospatiale during an ESA feasibility study for an advanced ocean colour monitor, the concept, if technically demonstrable, may have much wider application.

DR. M.L. REYNOLDS

ASTRODYNAMICS: ATTITUDE MOTION

The attitude motion session was attended by an average audience of about 60 who participated enthusiastically in the question and answer sessions. Among the more significant presentations, van der Ha showed how perturbation methods associated with celestial mechanics could be adopted to obtain a first order solution for attitude motion under body fixed torques. As a practical example, the spin-down effect observed on the ESA GEOS satellite was treated.

The main current effort in this field concentrates on the attitude dynamics of flexible spacecraft systems; owing to the increasing size of solar panels, antennae, booms, tethers and the perspective of future space stations, the treatment of flexibility, both in the assembly/deployment stages as well as in the operational on-orbit configuration, is now one of the central issues in attitude dynamics. As an example, Modi and Ibrahim described a relatively general formulation for use in simulating the librational dynamics of beam and plate type

flexible appendages. In general, such problems are very complex, involving non-linear, non-autonomous, coupled hybrid sets of differential equations. Several questions from the audience emphasised the need to keep computer CPU time at reasonable levels. As a second example of a large, flexible system, Bainum and Krishna modelled the disturbance torques induced by solar radiation pressure that are expected to provide principal perturbations on the attitude motion of the proposed Hoop/Column (122 m diameter) multi-beam communications satellite system, where stringent orientation pointing accuracy and mesh contour shape control requirements will be imposed. These two papers further emphasise the tendency towards interdisciplinary research with the integration of such fields as structural dynamics, astrodynamics, control theory, heat transfer, etc. required. The treatment of these problems can be greatly facilitated by developments in computer technology and, in particular, progess in computer generated graphics.

Two other examples of future large flexible space systems were treated by Swan, and Williams and Radley. In the former, the control of tethered connected systems in highly eccentric elliptical orbits was examined; the analysis was limited to the orbital plane and did not consider atmospheric drag (which could provide significant disturbances, especially in the out-of-plane motion). The latter paper described preliminary work on the level of a "Phase-A Study" for an Earth orbiting amateur solar sail spacecraft.

Sarychev and Gutnik obtained more general results for the classical problem of determining equilibria positions of orbiting gyrostats, previously treated by a number of authors (including Sarychev). There were several questions concerning the number of equilibria points and their stability; apparently very few are stable. Elyasberg and Pivovarav described the application of established algorithms for attitude determination, with an application cited for the Russian AES spacecraft.

Huang and Das treated the effects of random environmental torques and stochastic geometry on the pointing accuracy of spinning and three-axes stabilised satellites. A comparison was given between analog simulation and four analytical methods previously described at IAF Congresses.

DR. PETER BAINUM

SPACE SAFETY AND RESCUE SYMPOSIUM

Space Safety and Rescue

Papers clustered for the most part on man-made space debris, offering analyses of cost and feasibility of removing spacecraft from orbit; the debris population that comprises the hazard and the provision of structural integrity despite debris impingement. A classic analysis was presented of the uncertainties in accurately predicting orbital lifetimes as contrasted with re-entry trajectory prediction which took the view that, in advance of launch, it should be a responsibility of those conducting space missions to present sufficient information to enable a population located within the re-entry footprint to determine the risk to them.

An important implication of the debris papers is that nothing significant can be achieved until international attention in its broadest spectrum is engaged.

Apollo 11 astronaut Edwin Aldrin put forward an original viewpoint that a consideration in the selection of space station orbits should be their accessibility to crews of other space stations for rescue purposes.

Methodologies conceived at the start of the manned space programme and changes over the ensuing 30 years were traced as a basis for outlining what the safety focus in the near- to longer-term future needs to be; it made 'transparent' the enduring safety philosophies that prevail regardless of changing focuses.

In respect to Space Shuttle ground processing, a clear understanding was necessary of how the need to meet successive launch dates can create competition for the specialised work areas and cause pressure to flaunt safety precepts; it offered approaches to managing the multiple processing without time delays or jeopardy to safety.

Earth Safety and Disaster/Distress Response Employing Space-Based Systems

An experimental transmitter of coded-symbol information for use by field personnel at the site of a disaster to the disaster-response headquarters was reported by the United Nations Disaster Coordinator's Office.

The contribution to be made by mobile satellite systems, one of which was described (Geostar), to safety, position determination and tracking for traffic control and rescue has recently been the subject of experiments on a widespread scale, though the concept goes back to the early satellite-applications investigations.

Steady progress was reported on designing a satellite-aided global distress response system that will replace and improve the performance of the present global system which has, not so far, utilised space-based systems as the basis for global compliance. The advantages of space-based proposals for the eventual international maritime system are under continuing assessment. The final phase of the demonstrations and evaluations is nearing completion. A penultimate question is the gain to the varied users of the system-that-evolves, in view of the differing user-operation situations and whether or not this will be universally/conclusively evident in advance of the next ITU WARC and the schedule for initiating implementation plans.

The ultimate questions remaining to be answered are those of the long-term commitment to the provision of satellites and the allocation of costs - complex institutional questions.

GLORIA HEATH

IAF CONGRESSES

1. 1950: Paris, France.	19. 1968: New York, USA.
2. 1951: London, UK.	20. 1969: Buenos Aires, Argent.
3. 1952: Stuttgart, Germany.	21. 1970: Constance, Germany.
4. 1953: Zurich, Switzerland.	22. 1971: Brussels, Belgium.
5. 1954: Innsbruck, Austria.	23. 1972: Vienna, Austria.
6. 1955: Copenhagen, Denm.	24. 1973: Baku, USSR.
7. 1956: Rome, Italy.	25. 1974: The Hague, Holland.
8. 1957: Barcelona, Spain.	26. 1975: Lisbon, Portugal.
9. 1958: Amsterdam, Holland.	27. 1976: Anaheim, USA
10. 1959: London, UK.	28. 1977: Prague, Czechoslovakia.
11. 1960: Stockholm, Sweden.	29. 1978: Dubrovnik, Yugoslavia.
12. 1961: Washington, USA.	30. 1979: Munich, Germany.
13. 1962: Varna, Bulgaria.	31. 1980: Tokyo, Japan.
14. 1963: Paris, France.	32. 1981: Rome, Italy.
15. 1964: Warsaw, Poland.	33. 1982: Paris, France.
16. 1965: Athens, Greece.	34. 1983: Budapest, Hungary
17. 1966: Madrid, Spain.	35. 1984: Lausanne, Switzerland.
18. 1967: Belgrade, Yugoslavia.	

SATELLITE DIGEST-181

Robert D. Christy
Continued from the February issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1601 1984-104A, 15326

Launched: 0932, 27 Sep 1984 from Plesetsk by C-1.
Spacecraft data: Not available.
Mission: Possibly radar calibration.
Orbit: 475 x 515 km, 94.52 min, 65.84°.

COSMOS 1602 1984-105A, 15331

Launched: 0601, 28 Sep 1984 from Plesetsk, possibly by F vehicle.
Spacecraft data: Probably a cylinder, with two Sun-seeking solar panels, length about 5 m, diameter about 2 m, and mass around 2000 kg.
Mission: Remote sensing over ocean areas.
Orbit: 634 x 667 km, 97.80 min, 82.54°.

COSMOS 1603 1984-106A, 15333

Launched: 1400, 18 Sep 1984 from Tyuratam By D-1 (-E?).
Spacecraft data: Not available.
Mission: Probably a launch vehicle engineering test.
Orbit: Initially low circular, about 88 min, 51.6°, then within one orbit of launch, transferred to 814 x 854 km, 101.60 min, 66.56°; then immediately to 850 x 856 km, 102.02 min, 71.01°.

COSMOS 1604 1984-107A, 15350

Launched: 1950, 4 Oct 1984 from Plesetsk by A-2-e.
Spacecraft data: Possibly similar to the Molniya satellites, having a cylindrical body with a conical motor section at one end, and with power being provided with a 'windmill' of six solar panels. Length about 4 m, diameter 1.6 m and mass around 2000 kg.
Orbit: Initially 594 x 39408 km, 710.63 min, 62.90°, then raised to 606 x 39716 km, 717.12 min, 62.91°.

STS-41G 1984-108A, 15353

Launched: 1103*, 5 Oct 1984 from Kennedy Space Center.
Spacecraft data: Delta winged vehicle, 37 m long and 24 m across, with mass around 70 tonnes (excluding payload).
Mission: Flight by Orbiter *Challenger* with crew of seven, consisting of Robert Crippen, Jon McBride, David Leestma, Kathryn Sullivan, Sally Ride, Paul Scully-Power and Marc Garneau of Canada. Part of the payload was the SIR-B (Shuttle Imaging Radar) for high resolution terrain imagery. Photographic images were obtained for mapping purposes using a high resolution, large format camera. Other activities included oceanographic and Earth surface observation by the crew, simulation of refuelling techniques (undertaken during an EVA by Leestma and Sullivan - the first US woman to make an EVA) in preparation for a mission involving Landsat 4 in 1987, and the launching of ERBS. *Challenger* landed at Kennedy Space Center on 13 Oct.
Orbit: 346 x 359 km, 91.56 min, 57.00°.


The crew of 41G.

ERBS 1984-108B, 15354

Launched: 1930, 5 Oct 1984 from the payload bay of *Challenger.*
Spacecraft data: Designed for launch by Shuttle, and to fit the payload bay, the Earth Radiation Budget Satellite is roughly triangular in shape with base 4.57 m, height 3.81 m and depth about 1.5 m. Power is provided by a pair of solar panels at right angles to the apex of the triangle.
Mission: To study the interaction of the Earth as a radiator, and the radiation energy received from the Sun.
Orbit: Initially released by the remote manipulator arm into a similar orbit to *Challenger,* ERBS then raised its orbit by several hours of low thrust engine operation to 599 x 608 km, 96.72 min, 56.00°.

COSMOS 1605 1984-109A, 15359

Launched: 1443, 11 Oct 1984 from Plesetsk by C-1.
Spacecraft data: Cylinder with domed ends, enclosed in a drum-shaped solar array with length and diameter both about 2 m. The mass may be around 700 kg.
Mission: Navigation satellite.
Orbit: 951 x 1019 km, 104.86 min, 82.94°.

NOVA 3 1984-110A, 15362

Launched: 0145, 11 Oct 1984 from Vandenberg AFB by Scout.
Spacecraft data: Not available.
Mission: US Navy navigation satellite.
Orbit: 1155 x 1202 km, 109.02 min, 90.07°.

COSMOS 1606 1984-111A, 15369

Launched: 1747, 18 Oct 1984 from Plesetsk, possibly by F vehicle.
Spacecraft data: Possibly similar to Cosmos 1602.
Mission: Probably an electronic ferret.
Orbit: 631 x 655 km, 97.75 min, 82.52°.

COSMOS 1607 1984-112A, 15378

Launched: 1229, 31 Oct 1984 from Tyuratam by F-1.
Spacecraft data: Not available, but probably several tonnes mass.
Mission: Military ocean surveillance, using radar.
Orbit: 250 x 264 km, 89.66 min, 65.01°, maintained by a low thrust motor.

STS-51A 1984-113A, 15382

Launched: 1220, 8 Nov 1984 from Kennedy Space Center.
Spacecraft data: As STS-41G.
Mission: Flight by Orbiter *Discovery* the crew consisted of Frederick Hauck, David Walker, Anna Fisher, Joseph Allen and Dale Gardner. The main objectives were to launch two satellites and to recover Palapa B2 and Westar 6, which were left in unusable orbits by faulty rocket stages after the STS-41B mission (1984-11). Prior to the recovery, both satellites' orbits were lowered to approx 350 x 370 km. Palapa was recovered on Nov 12, and Westar on Nov 14. *Challenger* landed at the Kennedy Space Center at 1200, 16 Nov 1984.
Orbit: 294 x 298 km, 90.24 min, 28.47°, then raised to 353 x 370 km, 91.58 min, 28.46° for rendezvous with the satellites.

ANIK D2 1984-113B, 15383

Launched: 2130, 9 Nov 1984 from the payload bay of *Discovery.*
Spacecraft data: Standard Hughes HS-376 vehicle, cylindrical in shape with length about 2.8 m (extending to 6.7 m on deployment of solar array) and diameter 2.2 m. The mass in geosynchronous orbit is about 1100 kg, reducing to about 570 kg on depletion of fuel.
Mission: Canadian communications satellite to be stored in orbit for up to two years.
Orbit: Geosynchronous above 111.5° W longitude.

SYNCOM IV-3 1984-113C, 15384

Launched: 1200, 10 Nov 1984 from the payload bay of *Discovery.*
Spacecraft data: Cylinder about 3 min long, and 4.2 m diameter.
Mission: US Navy communications.
Orbit: Geosynchronous above South America.

FROM THE SECRETARY'S DESK

Flight-Path

Charles Walker, Shuttle Mission 41D Payload Specialist and Fellow of the Society, dropped in to see us during a short visit to London. Charles 'discovered' the BIS while at Purdue University in 1966. He says he was thoroughly fascinated by our journals and determined to join.

Charles provided an interesting account of his flight last June when he was specialising in pharmaceutical experiments. He is due to go up for the second time on flight 51D next March - and may even fly again, for the third time - in a launch presently scheduled for August next.

In due course Charles anticipates that pharmaceuticals will be produced in space on seven day flights, providing materials which will be available for sale in the late 1980's. This work will lead, eventually, to a free flyer from 1989 onwards - a 5000 lb factory in space with a total weight of some 20000 lb, but not pressurized.

Charles mentioned that there are currently some 75 astronauts assigned to the NASA Astronaut Office on active duty. About a half are mission specialists. At the present rate, all will soon be accumulating practical flight experience.

We were pleased to welcome a distinguished visitor to the Society, Charles Walker (centre), payload specialist astronaut on the Shuttle. At left is Len Carter; at right, Dr. Les Shepherd, Chairman of the BIS International Liaison Committee.

European Space Symposia Proceedings

The American Astronautical Society has just brought out the proceedings of the 18th European Space Symposium held in London last year and which attracted papers of an exceptional high quality. The volume which has the theme of "SPACE - A Developing Role for Europe" runs to 302pp and sells for $40 (hard cover) or $30 (soft cover) but Members of the Society can deduct a 20% discount on ordering copies direct from the Publishers, *viz* Univelt Inc., P.O. Box 28130, San Diego, California 92128, USA.

The same applies to the proceedings of the 17th European Space Symposium, also held in London, but this time in 1981 and which, too, proved a great success. The theme was "Space in the 1980s and Beyond". At 302pp, the price is the same as for the 18th ESS volume.

Flying In

I adopt a suitable welcoming stance to all our vistors but none more so that to Dr. Ing. Alberto Jona, just celebrating his 80th birthday and now one of our oldest members.

We always adopt a welcoming stance.

Dr. Jona, from Rome, has spent the whole of his life in the aeronautics field and is still as active, as consultant, as ever.

We had a fine time discussing some of the seaplanes which participated in the pre-war Schneider trophy. Dr. Jona was a young engineer then, engaged in tuning engines to be used in the Italian entry. The ultra light-weight seaplane he worked on used two engines, in tandem layout.

Reminiscences ended on a suitable note. His response to the comment 'You must have known everyone in the aeronautics field then' brought forth the ready quip 'Yes, but it's an example not to be followed!'

Well Organised?

Those at meetings invariably say whether it was well organised or not, apparently oblivious of the fact that, really, only one third of the meeting actually lies under the organiser's control at any one time.

We divide our meeting into three main segments, with interfaces between all three, running into thousands, in the case of Space '84, all of which have to be syncrhonised exactly, i.e.

1. The part we can control and which we try to keep flexible because too tight a control brings a new range of problems.
2. Inanimate objects. These are similar to Acts of God. They include projectors, fuses and bulbs, things that break, collapse or won't fit, vehicles that become immobile (in the case of Space '84 our van developed three punctures on the same day!), temperamental microphones and the like. All occur without warning.
3. Other people. These are those over whom the organiser has no direct control. They include printers, exhibiters, subcontractors, staff, airlines, coach drivers, the Chairmen and Speakers and even the tea ladies. For example, a meeting might finish too early, or very late, yet teas, coffees and

biscuits have to appear instantaneously.

Similarly, music might fill the whole building, simply because someone grew bored, needed cheering up, but forgot to switch off interconnecting sound circuits.

This is why, in accepting compliments with becoming modesty, one keeps one's fingers crossed.

It's really just a matter of good luck.

Missing Persons

The daily chore of changing members' addresses goes fairly well, in spite of an occasional hiccup. The main problem lies not so much in recording changes but *getting* them in the first place.

The queerest things happen. Sometimes we get a new address only to find that the member has immediately moved away again. Sometimes we are asked to delete an old address but are not told the new one. Sometimes the letter doesn't give any address (old or new) at all!

Nowadays, we rarely get caught out by those, mainly American members, who put their addresses only on the envelopes. We attach envelopes firmly to the letters until we are absolutely sure that the address is intact on the letter inside. For good measure we check all the enclosures too - to see if these are really complete e.g. no pages missing from documents, that cheques enclosed are signed and not dated two years ago (or hence), and even that they are *for* us!

But how does one explain a magazine returned marked "Not known here for over 12 years," when the member writes from exactly the same address again, months later, to complain?

We record changes daily but it sometimes happens that labels have already gone to the printers so the magazine is sent to the old address. The same thing can happen where a member requests a change of magazine. In both cases changes are made effective from the next run.

Join SOPL (*Save Our Postman's Legs*)

Our despatch record for magazines is extremely good but there is always the chance that delays in printing or production put us back a week or two. To avoid receiving letters from members complaining about late delivery we pre-dated issues i.e. the March issue was brought forward for dispatch in February and so on, thus giving us (so it was fondly imagined) a breathing space.

It doesn't work. The March *JBIS* was ten days late owing to delays in dealing with proofs, even though it still went out in February.

In came the letters.

Site-Seeing

A correspondent expressed surprise that we found the site of our present HQ so easily, surmising that I was merely passing by one day, discovered the site for sale and clinched a deal. The sequence of events is true though it took much longer in practice and is only the end part of the story.

This particular chapter in our history began many years earlier, almost a decade ago in fact, when it became apparent that the Society needed more room if it was to grow. An attempt to find accommodation nearby met with limited success though the entire freehold of one ramshackle building was offered to us at a price which turned out to be its annual rental when it was redeveloped years later.

Thereafter, things became really acute. Ideas for relocating our HQ were so rife that they took on 'Will-o-the-wisp' characteristics, a matter hardly helped by members from Lands End to John o'Groats arguing that the HQ should be close to their personal residences.

Meanwhile, a plethora of Estate Agents in the London Area and Outer Suburbs were looking for suitable properties. Whenever one appeared on the market, we immediately set off to examine it and, if it had any potential, arranged for the Council to visit and appraise it also.

Thus, for a period of four or five years, we were heavily engaged in site-seeing all round London and trying to get our work done at the same time.

It was a great time for ulcers.

Self-Help Book

I've enjoyed several humorous American books on space recently and was immediately attracted to the latest *Lost in the Cosmos* by Walker Percy (Arrow Publications, Hutchinson House, 17-21 Conway Street, London W1P 6JD., 1984 £2.95) not only because of its whimsical title but also because its sub-title of 'The Last Self-Help Book' promised hope of redemption. As a great believer in hoisting oneself by one's bootlaces, I'm always in the market for new ideas.

Actually, the book is not really about space, even if one section poses the question 'Why is Carl Sagan so lonely?' Most is really philosophy e.g. 'How much good news can you stand about others without flinching.' The reference to the Voyager 19 designer whose probe arrived at Uranus only three seconds off schedule and 100 yards off course yet turned out to be one of the most screwed-up people in California is not really news.

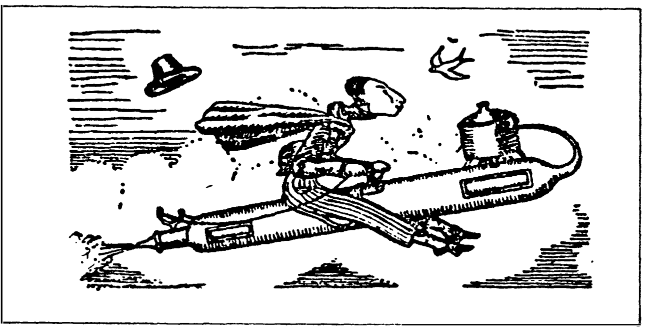
On the other hand, there's a lot about amnesia which can be helpful, while even *Daedalus* appears (p.167) - this time commanded by an experienced astronaut and 'with a spiritual leader aboard,' a noted Tibetan mystic.

Other useful sections are 'The Depressed Self' and 'The Impoverished Self' and - my favourite - 'The Orbiting Self' concerned with the problems we try to live with in the real world.

Punch Line

Soon after my book on Southwark (more specifically, Walworth) was published it was pointed out that I had omitted the most worthy Charles Golightly, of Gravel Lane, Southwark. 'Gentleman' - noted for his invention of 'a new apparatus for obtaining motive power' published in 1841 under Letters Patent No. 8771.

Sadly, no copy of his patent survives though his name was preserved for posterity by a contemporary cartoon in *Punch*.



Congratulations

Our congratulations go to Cyril Horsford on receiving the CVO (Commander, Royal Victorian Order) in the June 1984 Honours List.

Cyril is Deputy Clerk of the Privy Council.

BOOK NOTICES

The Voyages of Columbia
R.S. Lewis, Columbia Univ. Press, 562 W. 113th St., NY 10025, USA, 1984, 223pp, $24.95.

Space enthusiasts will know Richard Lewis' work for the excellent detail and personal insights that it provides on space topics. This volume on the Space Shuttle is no exception. The author covers the history of the Shuttle, its origin as part of a Space Station programme, its changes in design in the early 1970's and the later development problems. The greatest of the latter involved the main engines and the thermal protection tiles, forcing the initial launch date into April 1981. The author makes a convincing case that mistakes in choosing the appropriate methods of development for both led to lengthy delays.

The first mission, with astronauts John Young and Robert Crippen, is covered in detail. The following four test flights are described to a lesser extent but, illustrating that by the end of them in November 1982, Space Shuttle *Columbia* had proved herself to be a truly remarkable flying machine.

The First 25 Years in Space
Ed. A.A. Needell, European Ltd., 3 Henrietta Street, London WC2E 8LU, 1984, 152pp.

This volume records the proceedings of a symposium held at the National Air and Space Museum in Washington D.C., to commemorate the 25th Anniversary of the launch of Sputnik I on 4 October 1957. It falls into three main sections. The first considers motivations for going into space and how these have evolved over the past quarter-century. The second emphasises the economic aspects of space activities and suggests how these might be enlarged in future. The third considers the scientific component of the proceedings. It is interesting to see it spelled out that, contrary to views held by many in the UK, science has never been the main driving force of the US space programme, any more than the space programme has been the main driving force of science. As a rough measure, 10% of the American space programme has been devoted to scientific objectives or, to look at it from another angle, 10% of the US scientific programme is space-orientated.

Planetary Nebulae
S.R. Pottasch, D. Reidel Publishing Co., P.O. Box 17, 3300 AA Dordrecht, Holland, 1984, 322pp, $43.

Many books exist which describe the physics of nebulae generally but this must be the first, in more than 20 years, devoted solely to planetary nebulae and undoubtedly the first to provide a detailed discussion of their evolution.

Two hundred years ago it became apparent that cloud-like objects existed in the sky and which, because of their hazy appearance, were called nebulae (Latin for clouds). The French astronomer Charles Messier (1730-1870) catalogued many of these objects, mainly to avoid confusion in his search for comets. This catalogue, published in 1784, contained 103 entries. In the 18th century telescopes were poor, the images not always sharp and photography still undiscovered so controversy arose as to the nature of these nebulae objects. William Herschel (1738-1822) concluded that most could be resolved into stars, but added 2,000 more over a seven year period. However, he set aside a class of nebulae which seemed distinct from the rest and called them planetary nebulae, mainly because their appearance vaguely resembled the greenish disc of a planet, adding, in 1791, that they consisted of 'a most singular phenomenon' *viz* a star surrounded by a faint luminous atmosphere, more or less of circular form.

Planetary nebulae undoubtedly represent a late stage in stellar evolution, an area of considerable interest, for the idea of evolution from Red Giant to planetary nebulae seems plausible, at least. So a major purpose of this book is to provide an in-depth summary of present knowledge of planetary nebulae, not only for the benefit of students but also for research astronomers whose field of interest extends into that area. At the same time, an endeavour has been made to put together a substantial body of reference material for the use of those active in the field. This reference material, presented mainly in tabular form, consists of data concerning individual nebulae besides those atomic parameters needed for calculating nebular emission.

The book also considers the distribution of planetary nebulae in our Galaxy. All the time, the number of planetaries continues to grow. Whereas in 1918 these were considered rare, with fewer than 150 known, by 1979 the number had jumped to nearly 1500.

Astronomy and History (Selected Essays)
O. Neugebauer, Springer-Verlag, Heidelberger-Platz 3, D-1000 Berlin 33, Germany, 1983, 538pp, DM 56.

This is a collection of 43 papers (three in German) on a variety of topics relating to ancient and medieval astronomy, reprinted from many sources and falling into five categories depending on source *viz* General, Egyptian, Babylonian, Greco-Roman and Medieval.

All illustrate the important role played by astronomy in the early development of science and mathematics, though the text is not overtly either mathematical or technical.

Most of the topics deal with such fundamental concepts of positional astronomy as eclipses and planetary theory though others discuss related matters, e.g. the question of the extent to which Ptolemy relied on the earlier observations of Hipparchus, the water clock in Babylonian astronomy and even the orientation of the Pyramids.

The result is a compendium of an authoritative nature though its relatively fortuitous method of compilation produces a result lacking somewhat in cohesion.

Telescope Tides and Tactics
S. Drake, University of Chicago Press, 126 Buckingham Palace Road, London SW1W 9SD, 1984, 236pp, £20.70.

The publication of Galileo's *Starry Messenger* in 1610, detailing his startling observations with the newly-invented telescope, sparked immediate argument among the astronomers and philosophers of the day. The discovery of the satellites of Jupiter, for example, was pronounced a hoax or an optical illusion and was certainly a logical and theological impossibility.

The author, drawing on Galileo's scientific papers and the letters and notebooks of his contemporaries, has prepared an imaginative dialogue using the text of the *Starry Messenger* as a starting point in order to recreate the type of discussion which probably took place after its publication.

With the aid of archival material the author has unearthed a great deal of information to interest the lay reader e.g. descriptions of various and somewhat bizarre criticisms of Galileo besides discussions about his book. However, despite its factual base, the book is really a novel presenting an imaginary dialogue among three of Galileo's friends late in 1613.

As its title indicates, a further purpose of the book is to introduce Galileo's explanation of the tides and to discuss why Galileo's promised second book on the system of the world never appeared.

Clusters and Groups of Galaxies
Ed. F. Mardirossian, *et al*, D. Reidel Publishing Co., P.O. Box 17, 3300 AA Dordrecht, Holland, 1984, 659pp, $89.

Since the number of observable galaxies runs into tens, if not hundreds, of thousands, the large scale structure of the Universe, ranging from groups of galaxies to clusters and then to super-clusters presents, undoubtedly, one of the greatest

challenges facing the mind of man. Clusters range from simple doubles up to those with thousands of members and, finally, to super-clusters with dimensions ranging from tens of kiloparsecs to hundreds of megaparsecs.

The present volume deals with some aspects of this immense problem, including spatial distribution and clustering, observations by radio and Xx-ray, the problem of unseen matter and theories concerning both clustering and galaxy formation and evolution.

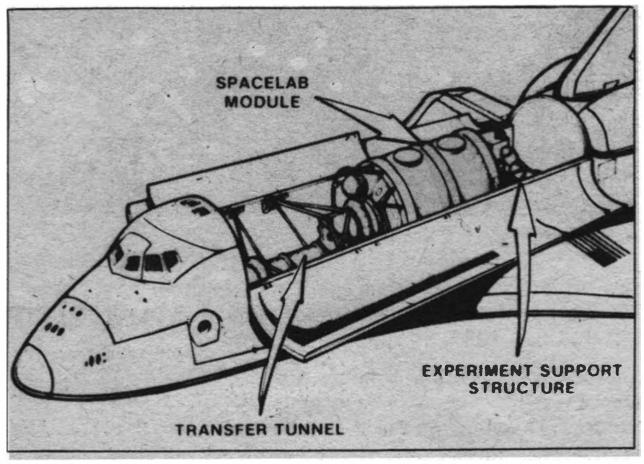
Particularly interesting is the account of recent studies of our own local super-cluster, the most recent hypothesis being that it is centred in or near the Virgo cluster and with our own local group occupying a somewhat outlying position. Besides our local or Virgo super-cluster, two other super clusters are studied in some detail *viz* those in Perseus and Coma/Abell 1367.

Interest in this absorbing topic is indicated by the fact that over 100 papers are included in the present volume. Admittedly, most are restricted to just a few pages but they, nonetheless, manage to impart an enormous amount of information. Several papers deal with satellite observations, particularly those from Exosat and the Einstein observatory.

Spacelab - Research in Earth Orbit
D.J. Shapland and M.J. Rycroft, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1984, 192pp, £11.95.

This book is about one of the most important (and most expensive) space programmes in Europe today, with a total cost of the order of 800 million US dollars. All the European member states (except Sweden) participated, with the main shares paid for by Germany (54.9%), Italy (15.6%), France (10.3%) and the UK (6.5%).

Spacelab- a manned laboratory to orbit the Earth with the Space Shuttle - represents Europe's first step towards involvement in manned space flight. This book charts the 12 year development of the Spacelab programme from its initial spark to its first launch aboard the Shuttle in November 1983. It also describes many behind-the-scenes activities which are essential to a project of this nature, together with the experiments actually performed on the first flight. These encompassed a wide range of scientific disciplines: early results are discussed



Spacelab layout.

and future alternatives suggested.

A particular problem which arose during development stemmed from the fact that Spacelab was being developed at the same time as the US Shuttle, with the result that many specifications for interfaces were left 'to be determined' rather than fixed at an early stage. The final changes which became necessary as attempts were made to synchronize the two programmes led to a two-year delay and increased costs. Delay in the Shuttle development proved even longer so that Spacelab was ready well before the first flight.

Spacelab is designed to play an increasing role in manned space flight in the future, with different payloads orbited three-four times annually.

The present volume describes, splendidly, both its attainments so far and some of its future dreams.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

DO YOU REMEMBER?

25 Years Ago...
11 March 1960. The first deep-space probe, Pioneer 5, is launched by Thor-Able. Pioneer sampled magnetic fields and particles in interplanetary space and returned data from distances of up to 36.5 million km.

20 Years Ago...
20 February 1965. Ranger 8 impacts on the Moon's Sea of Tranquillity following a 64 hour flight from Earth. It returned 7137 closeup images of the lunar surface before impact.

15 Years Ago...
17 February 1970. NASA announces that the Apollo Application Programme is to be redesignated the Skylab Programme. The name Skylab was proposed by Donald L. Steelman of the USAF while assigned to NASA.

10 Years Ago...
15 March 1975. The German satellite Helios 1 flies to within 45 million km of the Sun, making the first close observations of the surface and the solar wind. Helios detected 15 times more micrometeorites there than near Earth.

5 Years Ago...
22 February 1980. The Japanese Experimental Communications Satellite 2 (ECS-2) is launched from Tanegashima. Contact with the satellite was lost at the time of scheduled apogee motor ignition.

K.T. WILSON

EDITORIAL

Continued from p.97

underlined and with this realisation has come the integration and addition of ideas that would not even have been considered at one time, such as the rescue and repair of satellites.

The Shuttle programme was carried forward and developed in what must have been one of the most unstable eras, in terms of American Presidential elections. Not only were there swings between Republican and Democrat but there were also violent changes of attitude between different presidents of the same party. Those in charge of Shuttle development had to do the best they could in every changing circumstance.

The Manned Space Station is scheduled to be in orbit by 1992 (the 500th Anniversary of the epic voyage of Columbus). The re-election of President Reagan suggests stability during its development stages. With the next Presidential election due in 1988, it is probably too much to expect continuity of present space policies but the recent re-election has occurred during the initial period when the design had to 'gell.' From now on the Space Station concept will continue to progress, even if changes are required by later technical developments.

The UK and Europe should recognise this period of electoral stability and make use of it by joining the project. Full participation by other powerful contributors now will bring added advantages in stabilising this progressive development.

MEET THE UK ASTRONAUTS

The first Briton to travel into space is due to go aloft in 1986 aboard the Space Shuttle with a UK Skynet communications satellite. All four of the candidates in training - Nigel Wood, Richard Farrimond, Peter Longhurst and Chris Holmes - will be Guests of Honour at a special dinner to be held at Society headquarters on the evening of Friday, 21 June 1985.

This is a unique opportunity to meet the men who will be part of space history. There are only a limited number of places available, so early application is essential. The cost (including sherry, 4-course meal and a half bottle of wine) is £18 per person (a maximum of one guest per member); dress informal. Registration forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Top left: Nigel Wood (RAF), *top right:* Richard Farrimond (Army); *bottom left:* Peter Longhurst (RN); *bottom right:* Chris Holmes (MoD).

JBIS

The March issue of the Journal is devoted to 'Interstellar Studies.' The papers include:

- 'Suspended Animation for Space Flight,' by J. Hands.
- 'Can Population Grow Forever?' by P. Birch.
- 'Trend Analysis for Interstellar Ramjet Technologies,' by R.J. Stalker.
- 'On the Potential Performance of Non-Nuclear Interstellar Arks,' by G.L. Matloff.
- 'Non-Nuclear Interstellar Flight,' by G.L. Matloff and E. Mallove.
- 'Plasma Expansion in the Daedalus First Stage Engine,' by J.O. Elliott and W.K. Terry.

Copies of the Journal are available at a cost of £2 ($4) each, post free, from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

The February 1985 issue of *JBIS* is devoted to 'Space chronicle,' which includes the following papers:

1. "Spacesuit Development - The American Experience," by K.T. Wilson
2. "US Military Satellites, 1983," by Anthony Kendon
3. "The Flight of Able and Baker," by J.W. Powell
4. "The Soviet Venera Programme," by P.S. Clark.

Copies of the issue are available at a cost of £2 ($4) each, post free from The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. The May 1984, August 1983 and April 1983 'Space Chronicle' issues of *JBIS* are still available at a cost of £2 ($4).

DELUXE CERTIFICATES

Both Fellows and Members may now purchase high-quality certificates suitable for framing. These are 29.5 x 41.5 cm in size, printed in three colours and with the member's name hand-inscribed. They are available for only £5 ($8) post free.

When ordering, please indicate membership grade and allow six weeks for delivery. Provision for ordering these certificates also appears on the 1985 subscription renewal form.

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

£10,000 - FOR NOTHING

If every member who pays income tax completed a Deed of Covenant, which takes only a few moments, the Society would be **£10,000 better off** each year. The money is there, just for the asking.

Think what our Society could do with such a sum. Keep subscriptions down; mount an aggressive Space Promotion Scheme; a deeper involvement in education; expand its premises; improve its Library.

Just think, £10,000 extra to spend on some really worthwhile task *every year.* So why don't we grasp the opportunity with both hands? The snag is that *you,* the member, has to complete the form - not us. It's that easy.

So why not give us a call or drop us a line? Do your bit for space.

It will cost you nothing.

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Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01–735 3160.

NOTICES OF MEETINGS

Lecture
Theme: **COMMERCIAL LAUNCH VEHICLES**
By G.M. Webb

The context in which Europe will be competing commercially using its post-Ariane 4 series of launcher will probably be very different from the present situation; the viability of the various options open in the mid-1990's will be discussed.

To be held in the Socity's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **20 February 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Symposium
Theme: **EUROPE-US SPACE ACTIVITIES**

The **1985 Goddard Memorial Symposium**, in conjunction with the **19th European Space Symposium**, will be held at the NASA Goddard Space Flight Center, Maryland, USA on **28-29 March 1985** organised by the American Astronautical Society and co-sponsored by The British Interplanetary Society in association with other Societies.

Offers of papers are invited. Futher information is available from the Executive Secretary and registration forms will be available in due course.

Lecture
Theme: **PLASMA PHYSICS IN SPACE**
by Dr. D.A. Bryant
Rutherford Appleton Laboratory

Results from the three-satellite AMPTE mission, launched in August 1984 to explore by revolutionary new techniques the interaction of the solar wind with the Earth's magnetosphere and the comet-like behaviour of injected plasma clouds, will be discussed.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **1 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture
Theme: **COHERENT LIGHT FROM SUPERNOVAE**
By A.T. Lawton
President of the Society

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **15 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

One-day Forum
To be held in the Society's Conference Room, 27/29 South Lambeth Rd, London, SW8 1SZ on **Saturday, 1 June 1985**, 10.00 a.m. to 5.00 p.m.

Topic: **THE SOVIET SPACE PROGRAMME**

Subjects will include :

- History of the USSR Lunar Programme
- Cosmonaut Update
- Soviet EVA Experiments

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

Lecture
Title: **SATELLITE INSURANCE**
By R Buckland

Launching satellites into space is a risky business. No commercial project can go ahead without insurance to cover launch and other risks. This talk will describe the role that satellite insurance plays in the development of commercial activity in space.

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **12 June 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time, enclosing a stamped addressed envelope.

Lecture
Theme: **METEORITES: SURVIVORS OF THE EARLY SOLAR SYSTEM**
By Dr. A.L. Graham
Dept. of Mineralogy, British Museum

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **18 September 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:

20 Feb 1985
3 Apr 1985 — 1 May 1985
15 May 1985 — 12 Jun 1985

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

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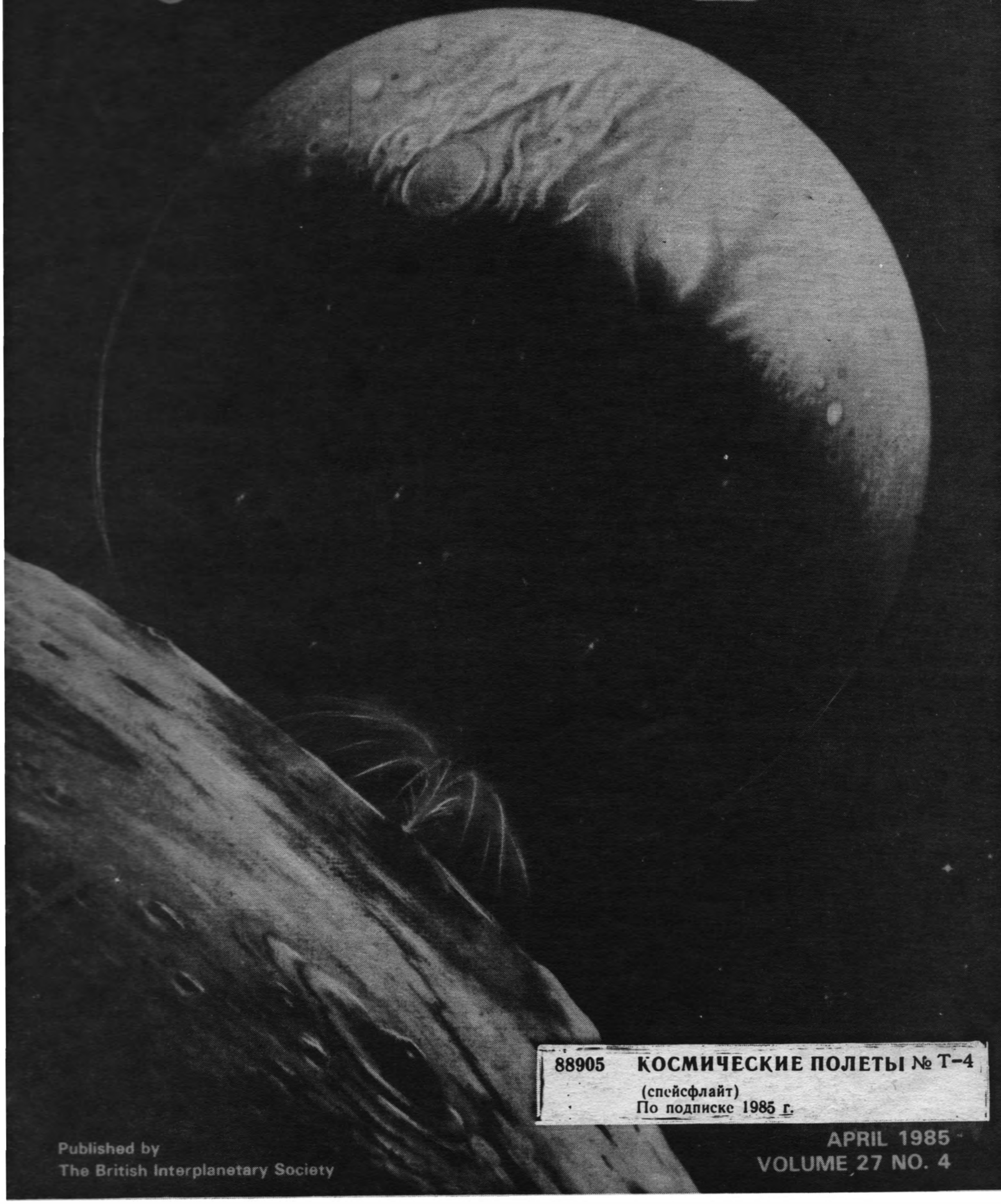

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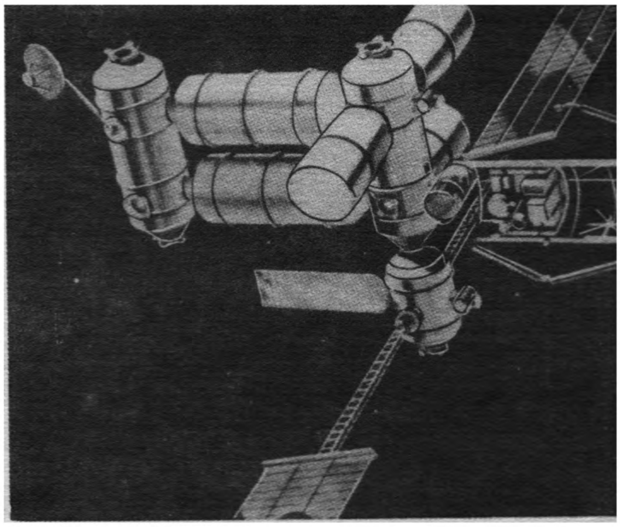
APRIL 1985
VOLUME 27 NO. 4

SPACE STATION PLANS

The US Space Station is the next major manned space project of the western world, with initial operations in orbit expected in the early 1990's. Plans for participation are being considered by most European countries, including the UK. Our Society, which has long advocated permanent manned bases in space, will contribute further to the discussions by providing updated reviews at a one-day symposium. The date is 17 April 1985, the venue HQ. A provisional list of papers to be presented by a panel of international speakers will include the following:



1. **'European Space Station Overview,' by F. Longhurst (ESA).**
2. **'Space Station Platform - Overview,' by Dr. R.C. Parkinson (BAe).**
3. **'User Requirements for Space Stations,' by I. Franklin (BAe).**
4. **'Space Station Pressure Compartment,' by Prof. Valleriani (Aeritalia).**
5. **'Application of Propulsion Modules to Space Station Infrastructure,' by D. Gilmour (BAe).**
6. **'Orbital Replacement Units for Space Stations,' (Provisional).**
7. **'Assembly and Maintenance of Space Stations,' (Provisional).**
8. **'European Overview of the Space Station Proposals,' by R. Gibson.**

The Symposium will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, England on 17 April, 9.30 a.m. to 5.30 p.m. The registration fee is £15 (non-members £17). Forms are now available from the Executive Secretary at the above address. The places remaining are limited so early application is advised.

1985 SUBSCRIPTION FEES

There is good news for all members: fees for 1985 will remain unchanged from 1984 in spite of rising costs.

Direct Debit Scheme

Our old Bankers Order system has been phased out. Direct Debit slips are now available from the Executive Secretary but, since they will not come into operation until 1986, a separate remittance for 1985 will have to be made.

Amounts payable for the calendar year January-December 1985 are as follows:

RATES

Members	Sterling	US Dollars
Under the age of 18 years	£16.00	$26.00
Between 18 and 20	£18.00	$30.00
21 years of age and over	£21.00	$36.00
Fellows	£23.00	$40.00

Age Allowance

A reduction of £4.00 ($6.00) is allowed to members of every grade over the age of 65 years on 1 January 1985.

JBIS and *Space Education*

The additional subscription payable for *JBIS*, where required as well as *Spaceflight*, is £20.00 ($34.00). For *Space Education*, it is £4.00 ($6.00).

Methods of Payment

Europe

(a) Please pay in sterling with a cheque which shows a UK address, where it can be paid.

(b) Cheques drawn in sterling payable at a bank in Europe must include £2.00 to defray charges and collection costs. Eurocheques have no charges *only* if the account number is written on the back.

(c) Banks which remit directly to the Society must be told to see that the sum is transmitted *free of deductions*.

(d) Remittances from Europe are best made by GIRC. Our GIRO account number is 53 330 4008.

USA and CANADA

(a) US dollar cheques can be drawn on a Bank which gives an address in the United States or in the UK. US dollar cheques drawn elsewhere need to be increased bv $8.00 to cover collection charges.

(b) US dollar notes are accepted.

(c) US or Canadian money orders can only be accepted if *expressed in Sterling*. Internal money orders from these countries i.e. those expressed payable in dollars will be returned as they cannot be cashed in the UK.

(d) Canadian bank remittances may easily be made in sterling drawn on their UK agents. If payment is made in Canadian dollars the current exchange rate may be used, plus the addition of 8 Canadian dollars to cover exchange and collection charges.

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CONTENTS

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EUROPEAN MAN IN SPACE

ESA's future programme contains many excellent proposals but suffers from lack of serious intent to meet the overwhelmingly important matter of manned space flight, with the development of a space transportation system to meet such needs as an overwhelming necessity. This is in major contrast with the situation in the USA and in the USSR where, from the outset, sending men into space has received the highest priority. Europe is bedevilled by the lack of offical recognition that man has a major role to play in space. This shows the difference in attitude between European space decision-makers and their American and Russian counterparts who have viewed space flight from the outset in its true perspective - in Neil Armstrong's famous words - as "a giant leap for mankind." In the eyes of policy makers in most other countries space is seen simply as a way of extending particular fields of scientific research, or of advancing areas of commercial technology such as telecommunications. This difference in approach derives, ultimately, from the fact that the real pioneers of astronautics had a major say in the evolution of the American and Soviet space programmes, though in other places they were accorded only minor roles in decision-making because they seldom carried enough status in the rigid establishments of such countries to enable their views to carry much weight.

In the USA and, no doubt, in the USSR, there is no serious debate now on manned versus unmanned space, though competition certainly exists for available funds between those responsible for areas of space research and technology not directly involving manned presence in space and who want to improve the capability to transport both man and massive equipment into space. In the countries of ESA the debate is evident but seems to be a one-sided contest between a powerful establishment contending that it would be a waste of money to send men into space and those who recognise manned space flight as both a necessary and logical development. Opponents of manned space exploration argue that nearly all space undertakings can be done remotely by automatic equipment. Within their own narrow concept of space technology, no doubt, this can be difficult to refute: after all, in an increasing number of industrial and scientific activities, here on Earth, we are turning to robotics to replace human labour. In the current limited European activities in space, the scales are weighted heavily in favour of automation. But there is no basis for assuming that what is true in a limited context is universally valid. An assumption like that totally ignores the eventual role of Man in space.

Continued overpage

COVER

Space artist and BIS Fellow David Hardy depicts the planet Jupiter as viewed across the volcanic surface of moon Io in this painting. The satellite is so close to its parent body that tidal forces provide the energy for an active interior. Notice the fine ring of material, discovered by Voyager, encircling the planet.
D.A. Hardy

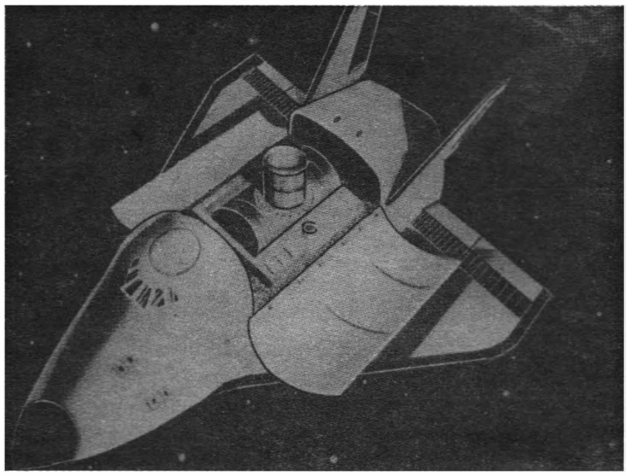
Man's expansion into an environment beyond the gravitational pit of his home planet is a fundamental step in his evolution. In the ultimate, humanity must seek new habitats with vast new resources and, eventually, evolve our species to adapt to quite alien environments. This, in the final analysis, is as basic as the emergence of life from the sea to the land which took place on our planet millenia ago. It dwarfs, incomparably, such acts as sending remotely directed instruments into space or using orbital platforms as vantage points from which to observe the surface of our world or to function as bases for microwave relays.

Even the public recognise this. What interests *them* is not space, as such, but space explored by human beings. The deepest human impulse is not just to know the facts about new environments, but to *experience* them. Space explored solely by instrument has little attraction for them - the ones who actually have to pay for it. Does the public rate a photograph of Mt Everest from a satellite e.g. of higher interest than Sir Edmund Hillary's epic climb?

For those with the longer perspective clearly in view, there is no question that Man has to be personally involved in space missions from the earliest stages. It is clear that this is the basis of the widely accepted philosophy on space enterprises in the USA and USSR, but quite naive to suppose that it carries any conviction in the offices of the space-policy makers and paymasters of Western Europe. Only the most compelling pragmatic arguments are likely to move the occupants of these quarters to abandon rigidly-circumscribed attitudes on such matters.

What, then, is the strength of the case for a serious manned-space programme in ESA? If one takes a relatively moderate view of space development, with due regard to the not inconsiderable allocation of funds required to cary it through, it clearly depends upon the degree of restriction of the European space programme. There is already a growing recognition among the Member States of ESA of the advantages of participating in the NASA Space Station programme. As this involves manned operations it must be supposed that European countries will wish for, eventually, an independent capability to lift its own operators into space. In space affairs, we, in Europe, possess considerable experience in the application of the Hitch-Hiker's Guide so it is to be assumed that our planners will take for granted an indefinite availability of American facilities for getting European personnel to their posts. However, even the most dogmatic opponents of manned space operations will find it hard, eventually, to withstand the pressure to achieve independence in human transportation. Such a need will develop inexorably as the enterprise progresses and its initiators start to look at the next stages of space exploitation. Here we have a situation that is surely one calling for the earliest possible forward planning, if for no other reason than the fact that the lead time involved in such advanced technology will be considerable.

A pragmatic approach to manned space flight by ESA implies the need to classify objectives into those which can be adequately met with unmanned satellites or spacecraft, and those which would benefit significantly or be dependent on the presence of man. The large-scale operation of space stations falls into this second category, as would the establishment of comprehensive bases on the Moon. Satellites, or even interplanetary spacecraft, whose purposes are relatively specialised do not require manning: in this class fall scientific and applications satellites as well as deep space and planetary probes, including particularly, those intended to enter extremely hostile environments. Size and cost are important considerations, as well as the matter of disposability. A very large or expensive satellite



The French 'Hermes' small shuttle concept.

might require occasional maintenance of a sort too complicated for remotely operated robots, so one of the functions of manned space stations would be that of providing bases from which servicing crews would operate.

Presently-envisaged ESA ventures, apart from possible participation in the USA Space Station programme, come into the category which does not require a human presence in space. However, it must be recognised that this is simply a temporary state of affairs, for as we move into the next century any meaningful space activity will necessarily involve direct human participation.

Various options are open to ESA and its member countries to meet independently the longer-term transport requirements of manned space flight. Some quarters have proposed that Ariane could be stretched to accommodate a man-carrying craft. This would scarcely be a viable proposition, however, since the vehicle is too small for the purpose and, notwithstanding continuing use by the USSR, expendable rocket launchers must be regarded as unsuitable for human transportation on a large scale. In any event it would be a highly expensive and probably pointless enterprise to embark upon the development of expendable rockets of the size and capacity now employed in the Soviets' programmes. The way to the future in manned space flight is, clearly, along the lines of adopting shuttle technology.

At the lowest level of independence, Europe might be able to hire, or purchase, US built shuttles on a purely commercial basis, in the same way that most countries purchase air liners today from the small number of manufacturing nations. The trouble is that this option carries a high political and strategic risk, and may not prove very satisfactory in the longer term. At the other extreme, Europe could develop and construct its own independent shuttle, possibly in collaboration with Japan, to share the high costs involved. The most sensible course remains however to enter into a joint international undertaking with the USA and build upon established American technology by developing an advanced shuttle. It would need to be implicit in such an arrangement, of course, that all participants would possess equal rights in subsequent construction and commercial use of the product.

This, surely, remains the most satisfactory course open both to Europe and to all other countries wishing to become seriously involved in manned space flight and the eventual exploration of space.

Since the above was written, representatives of Member States meeting in Rome have approved a new European initiative. Details will be given in the next issue.

UK NATIONAL SPACE PLANS

Two major British space initiatives were unveiled in late January: UK participation in the Space Station programme and the establishment of a UK National Space Centre, both of which have been strongly advocated by the Society.

Mr. Geoffrey Pattie, Minister of State for Industry and Information Technology, announced on 29 January that a 'British National Space Centre' is to be set up to improve the development of space technology in the UK and to co-ordinate policy more effectively.

'In establishing the BNSC we have recognised the need for a longer-term space policy and one that accepts that the dividing line between basic science and applications can often be rather arbitrary. Hitherto, the responsibility for space has been scattered around Government departments, academic institutions and industry and there is clearly a need for a much sharper focus for Britain's space effort. It was also obvious to us that the range of applications would be likely to multiply, especially in the field of Earth observation and remote sensing,' said Mr. Pattie.

The centre will probably be centered on Farnborough where there is already a successful joint technology programme funded by the Dept. of Trade and Industry and the Ministry of Defence. Further details will be announced in due course.

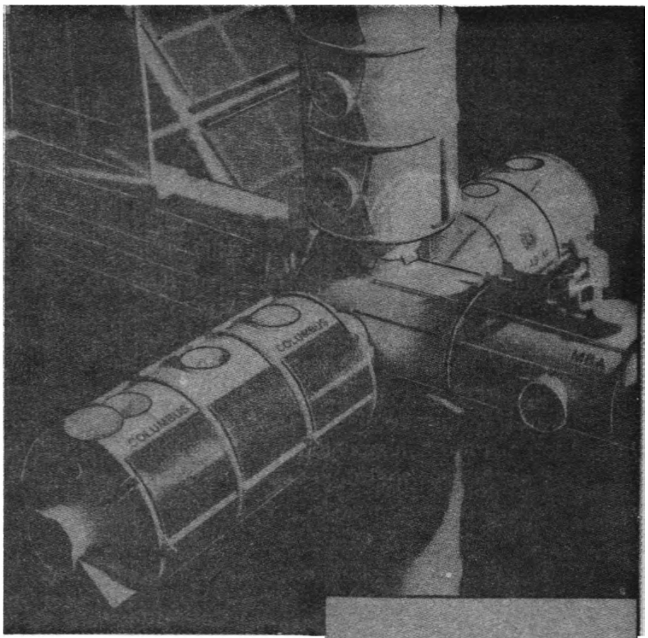
'We have been appraising the direction of British space policy in light of the new proposals for the ESA long-term programme (see pp.158-161 of this issue) and the invitation from President Reagan to participate in their Manned Space Station to be launched in 1992,' said Mr. Pattie.

Mr. Pattie led the British delegation to the ESA Ministerial Council Meeting in Rome on 30 and 31 January. 'We will be recommending our partners in ESA to respond positively to President Reagan's invitation. Britain will be urging the approval of a balanced space programme for Europe, building on the achievements already made by ESA, including strong emphasis on applications such as communications and Earth observation as well as front line science, launchers and space laboratories,' said Mr. Pattie before the meeting.

'The British contribution to Europe's 'Columbus' programme will be quite distinctive and exciting in that we are aiming to lead on the design of the man-tended space platforms [see pp.154-157 of this issue]. This element of the programme has been chosen because of its commercial promise and because it is particularly suited to the needs of British users. Joining the Space Station programme will give us access to all of the international Space Station facilities for techniques such as satellite re-furbishing and re-fuelling, essential if our space industry is to keep abreast of competition into the next century.'

CURRENT UK PROJECTS

British industry is currently prime contractor for nine satellites (3 further ECS, 1 x Olympus, 2 x Skynet IV, 1 x Giotto). They are currently working on significant orders for a number more, including 5 x Intelsat VI and Space Telescope.



The Columbus Space Station element will be Europe's contribution to the US programme. ESA decided at its meeting on 30/31 January to press ahead with studies for Columbus to be free-flying, i.e. unattached to NASA's station. *MBB*

Mr. Pattie, Minister of State for Industry and Information Technology.

The work to be done in advance studies in the Columbus programme over the next two years will cost some £50 million in total, with the UK bearing its *pro rata* share of 15%, or about £7 million.

British participation in the Columbus programme is based mainly on British Aerospace's proposal for a man-tended space platform. This could be launched into polar orbit directly from the Shuttle for Earth observation missions or it could co-orbit with the Space Station for missions in science or microgravity. This element of in-orbit infrastructure was favoured because it has more immediate commercial promise than many of the other elements and because it is less likely than other elements to be duplicated by the US. There will also be opportunities for other British companies in the Columbus programme, especially in data handling and communications.

At this stage, the decision is to join the definition stage (Phase B) of the Columbus programme at a cost of some £7m. The decision whether to proceed to the development Phases C and D will come at the end of 1986. A strict criterion for the success of Phase B is that our participation must buy access on a continuing and equal basis to all Space Station facilities.

The decision to establish a National Space Centre stems directly from the increase in space spending and supervisory effort that will come from the UK's participation in the Columbus programme. It does not represent any shift in policy in respect of the European Space Agency, rather that a better coordinated and more efficient UK space effort would result from the pooling of UK space research and development resources.

A National Space Agency

Sir, The necessity for setting up a National Space Agency is something of which I have been convinced for some time. However, I would caution proposing that the UK space effort be concentrated in a single project i.e. the space station. There are two other legs to the tripod of an integrated space programme:

1. Satellite technology
2. Launch system technology.

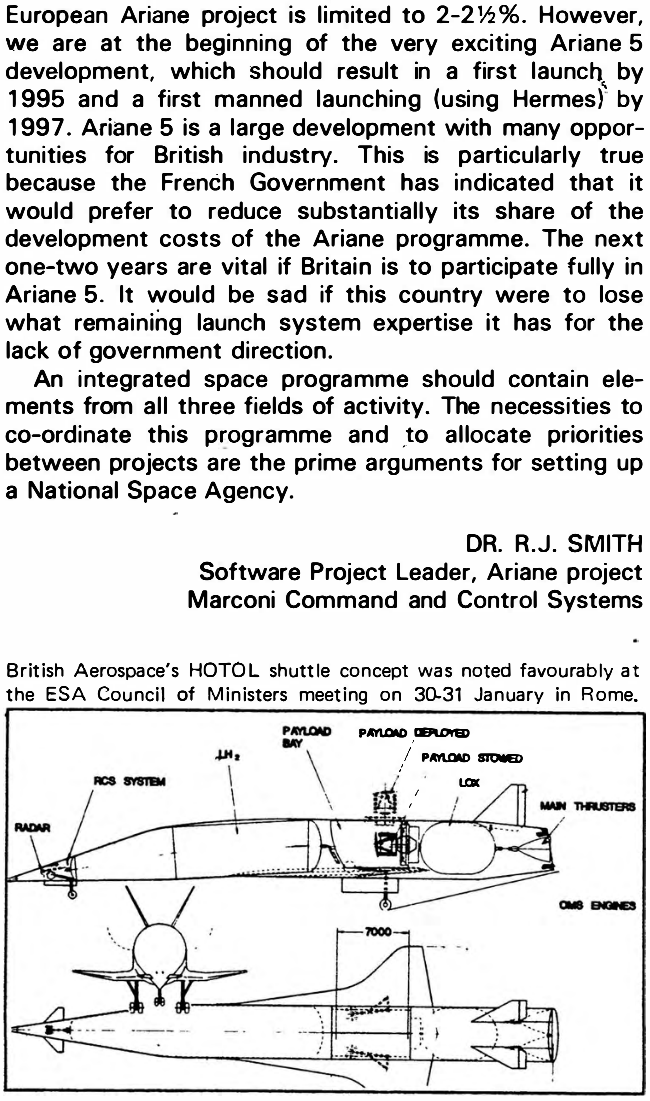
Almost every other national (or, in the case of ESA, international) space agency has programmes that address all three aspects. The first of these you have adequately covered in your editorial but the second also deserves priority. British companies have already made large investments in satellite technology. The resulting expertise provides a sound basis for future development. Further, Britain has an astronomical community second only to that of the United States' in size and research excellence. A strong case can therefore be made for a well planned programme of satellite-based space science to be a priority of any National Space Agency. Such a programme could provide world-beating scientific returns coupled with sound benefits in the stimulation of satellite technology in British Industry.

The third leg is one in which this country has lost most of the lead it had in ELDO days. British participation in the European Ariane project is limited to 2-2½%. However, we are at the beginning of the very exciting Ariane 5 development, which should result in a first launch by 1995 and a first manned launching (using Hermes) by 1997. Ariane 5 is a large development with many opportunities for British industry. This is particularly true because the French Government has indicated that it would prefer to reduce substantially its share of the development costs of the Ariane programme. The next one-two years are vital if Britain is to participate fully in Ariane 5. It would be sad if this country were to lose what remaining launch system expertise it has for the lack of government direction.

An integrated space programme should contain elements from all three fields of activity. The necessities to co-ordinate this programme and to allocate priorities between projects are the prime arguments for setting up a National Space Agency.

DR. R.J. SMITH
Software Project Leader, Ariane project
Marconi Command and Control Systems

British Aerospace's HOTOL shuttle concept was noted favourably at the ESA Council of Ministers meeting on 30-31 January in Rome.



A British Space Agency

Sir, Further to the editorial in January's *Spaceflight*, I wholeheartedly agree that Britain should have its own space agency. All the points made are valid though I feel the most important is the first - that of a 'focus' for UK space activities.

So much of astronautical research is done in a relatively small way in these Isles that the overall world-wide impact of British space research has been lessened, probably because most people never get to hear about it. Over recent years the Science and Engineering Research Council have become more aware of media interest and have, at least, been providing press information and conferences, but it does not represent industry. Likewise, British Aerospace is aware of what good publicity can do, but these are just two parties in a much wider field; an overall Agency could channel all activities for creation, co-ordination and that all-important focus.

It is ironic that Britain is conspicuous in space-faring nations (large and small) by not having a space agency. France, Germany, Japan, Sweden and even Israel have their own agencies.

Just what to call an organisation is perhaps the least of the problems. Perhaps 'British Space Agency' would suffice.

MAT IRVINE
Herts

The importance of a UK national space agency reflected in these items of Correspondence was emphasised by the subsequent announcement described on p.147. The steps recently announced have been advocated in a number of *Spaceflight* editorials. *-Ed.*

The Media and Space

Sir, The national press, radio and TV are editorially controlled by people who grew up with Apollo and who, like many, saw it as a glorified extravaganza with little benefit to Mankind. Apollo overshadowed those benefits.

There are no longer, as there were in the 1960's, aerospace correspondence who are able to concentrate on space. Space is now something handled (sometimes reluctantly and not very well) by science correspondents and technical editors.

Despite the achievements of companies such as British Aerospace, Britain's overall participation and interest in long term space projects is pitifully small. The media, therefore, reflect this to a degree. There is no great space goal to fire the imagination of the public. Only a manned flight to Mars would do it, not a Space Station, I'm afraid. As far as public reaction is concerned, films like *Star Wars* and *Close Encounters* were more exciting than the real thing.

Despite having shown little interest in space recently, I feel sure that the UK media will go overboard again when the first British astronaut flies in 1986 - with superficial and inaccurate enthusiasm as usual. Then, days later, it will all be back to normal!

TIM FURNISS
Surrey

Space Coverage

Sir, I read your October 1984 issue deploring the lack of news coverage of space happenings. In corresponding with friends overseas I have been made keenly aware of

this problem. Even here in the US the Shuttle liftoffs receive no more more than 10 minutes' live coverage from the TV networks and the landings even less.

NASA has its own TV network which it uses to distribute mission coverage to whoever may be interested. All that is required to receive it is a common home satellite TV receiver. Of course, this really doesn't help any European space-watcher as the satellite is much too far west for reception.

MIKE SMITHWICK
California, USA

The Wanstead Maypole

Sir, I can add some further information to the observations of James Bradley (*Spaceflight,* March 1985). His 122 ft focal length telescope was given the slightly irreverent but extremely descriptive title of The Wanstead Maypole by the local inhabitants - and this to what was, for a time, the largest telescope in the British Isles and possibly all of Europe.

The telescope was built at Wanstead Park (exact location unknown) by James Pound assisted by his nephew Bradley between 1717 and 1718.

The telescope's construction was rendered possible by two very generous donations. Christiaan Huygens presented the Royal Society with an object lens of 122 ft focal length. This was in 1691. It was first tried by a Dr. Denham of Upminster who pronounced it to be "of excellent quality."

The construction of the telescope is fully described in Huygen's *Astrocopia Compendiaria* folio 1684. By 1717 the lens had been returned by Denham and reloaned to James Pound - but how best to use it?

This was solved by the second donation. The populace of the Strand erected in 1661 the largest Maypole they could manage. It was 124 ft tall and was erected by a small army of seamen despatched by the Duke of York. This was in direct defiance of an Act of Parliament and was intended to herald the Stuart Restoration.

In due course the pole rotted away and was replaced by a new and even taller version in 1713. In 1718 this second pole was taken down and still in very good condition was bought by Sir Isaac Newton and sent as a free gift to Pound and Bradley at Wanstead.

Unfortunately, there was no band of stout seamen to erect it and Pound and Bradley had to organise it themselves. Pound was a careful man and detailed the expenses of hoisting the pole. They make interesting reading:-

1717 Sept. 18th
"Tin and Brasswork for Huygens Telescope" 4/6

1718 Apri. 25th
"By an eye glass for the Long Telescope" 2/6

1718 May. 13th
"By drink for Men who raised the Pole" £2.0.0

1718 May. 16th
"By several Men, paid them ½ days work for assisting in raising the pole.". 17/-

One can only assume that the main task was carried out in fine humour and good spirits!

The Wanstead Maypole was put to very good use by Bradley and Pound. They observed "all five Satellites of Saturn" and Bradley, in particular, used this instrument to prepare "extremely accurate tables for the major satellites of Jupiter."

This was intended to assist in the determination of longitude at sea but the tables proved so accurate that they played a major part in securing Bradley's election as Savilian Professor of Astronomy at Oxford University.

He was elected on 31 October 1721, admitted to office on 18 December and read his first lecture 26 April 1722.

Sadly, on 16 November 1724, the Rev. James Pound died and in 1728 we read of Dr. Bradley regretting that the Maypole was now broken and useless.

On 20 June 1718 the Rev. Mr. Bradley, Savilian Professor of Astronomy at Oxford, delivered to the Society the glass and old furniture of Mr. Huygen's large telescope. Thus, the remains of the Maypole were returned to their original home - where they still reside.

A.T. LAWTON
President, BIS

US Navy Satellite

Sir, I'm afraid that Max White ('Correspondence,' *Spaceflight,* February 1985) has misread the point I was making in my earlier letter (November 1984, p.392) about the LIPS satellite. The satellite was based on the plume shield that is normally discarded in orbit and therefore the LIPS launch would not produce more objects in orbit than a normal Whitecloud launch, nor would the visual appearance of LIPS be very different from that of the normal discarded plume shield. What singles out 1983-08 as the likely launch is that the B object has been officially identified as a payload and transmitting frequencies have been given, while for previous launches the B object has been a piece of debris. Thus the object 1983-08B that Mr. White observed would have been LIPS and not a rocket body as he suggests. My feeling is that Whitecloud, like DMSP, remains attached to its rocket body in orbit.

Incidentally, some sources refer to the satellite as LIPS 2, raising the question of what happened to LIPS 1. If my identification of 1983-08B is correct, the obvious suggestion is that LIPS 1 was lost with the previous Whitecloud payload in the Atlas launch failure of December 1980.

G.R. RICHARDS
Surrey

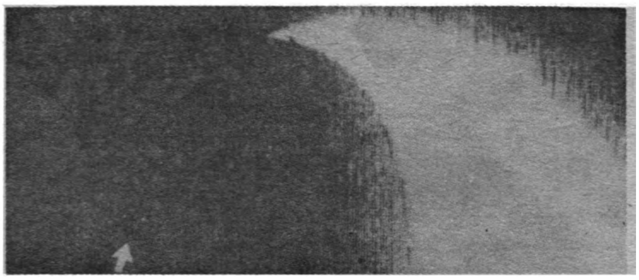
Surveyor Laser Target

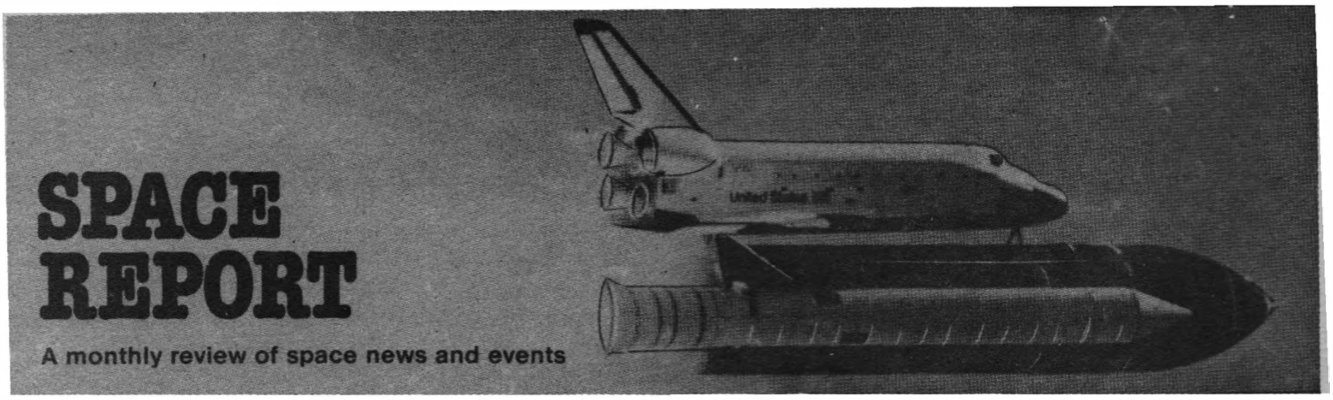
Sir, I know that laser beams are frequently shot into space for range-finding to satellites but what does it look like from the targets' points of view?

L.F. BATES
Newcastle

Reply:

The easist way of answering this query is by reproducing the picture nearby. It was taken by the US Suveyor 7 lunar soft-lander in 1968 as it was sitting on the Moon with its TV camera pointing back towards Earth. The two bright dots (arrowed) on the Earth's night-side are, in fact, laser beams from the Table Mountain Observatory in California and the Kitt Peak National Observatory in Arizona.





SPACE PROBES

GALILEO ASTEROID FLYBY

NASA Administrator James Beggs has approved the addition of an asteroid flyby option to the Galileo mission and a change in the Jupiter arrival date from August to December 1988. This will allow planners to make the decision *after* launch whether to fly past Amphitrite in December 1986.

The approval follows two years of study by numerous scientific groups, mission designers and officials. Galileo, designed to orbit Jupiter and send an instrumented probe into its atmosphere, is scheduled for a May 1986 launch by the Shuttle and a Centaur upper stage.

The National Academy of Sciences, as well as NASA's Solar System Exploration Committee (SSEC), has identified the close investigation of asteroids as an essential element of a balanced planetary exploration programme. The flyby has the endorsement of the Galileo Project Science Group and the Small Bodies Working Group of the SSEC.

The flyby will be treated as an additional and not a primary mission objective, and will not be allowed to compromise the basic mission objectives nor add any risk to the already ambitious planetary mission.

Amphitrite is in a near circular orbit in the middle of the asteroid belt at 2.5 AU from the Sun (the Earth's distance is one AU). At about 200 km in diameter, it is one of the larger of the minor planets. The flyby distance will be determined by safety considerations. A specially-convened Hazards Workshop has concluded that, with a 10,000 to 20,000 km flyby distance, the hazard to Galileo is no greater than merely flying through the asteroid belt, as has already been done by four Pioneer and Voyager spacecraft.

From Earth, Amphitrite appears as the 12th. brightest asteroid and has fluctuations suggesting a rotation period of 5.39 hours. At that rate, most of the surface can be photographed and scanned by Galileo's mapping spectrometer. Analysis will reveal size, shape, mass and density, exact rotation rate and pole orientation, and detailed surface morphology and mineral composition. Together, these will allow scientists to determine whether Amphitrite is a primitive accumulation of solar nebulae condensates or an evolved body that is a fragment, or perhaps a core, of a broken-up minor planet. It might be possible to decide whether Amphitrite and other asteroids are sources of many of the meteorites that fall on Earth.

This first encounter with an asteroid will also supply 'ground truth' for interpreting many previous and forthcoming ground-based observations of other asteroids.

Amphitrite, the 29th asteroid discovered, was detected by Albert Marth in London at the William Bishop Observatory on 1 March 1854. The asteroid was named by Bishop after one of the wives of the mythical god Neptune.

A new trajectory, containing both Amphitrite and Jupiter and constrained by the launch vehicle energy and existing launch window, has been developed. This will result in a delay in the Jupiter arrival date from 29 August to 10 December 1988. The effect on the Jupiter mission will be minor. Since the flyby requires added expenditure of propellant in the early mission phase, the number of tour orbits of Jupiter would be decreased from 11 to 10. Consequently, the length of the tour has been extended from 20 months to 22 months to permit the achievement of all the major objectives previously encompassed by the 11 orbit tour. Major added costs, estimated at $20-25 million, are attributable to a five month mission extension due to the delayed arrival date and increased tour time.

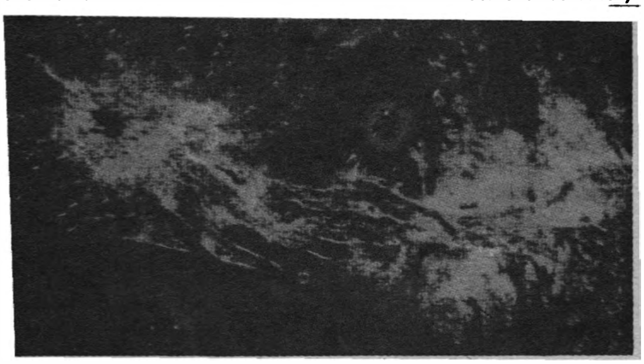
RESULTS FROM VENERAS 15 & 16

Results from the Soviet Venus orbiters, Venera 15 and 16, were published by the USSR last October, a year after the craft arrived at the cloud-covered planet, writes Brian Harvey. The information was made available by V.M. Kovtunenko at the IAF Congress in Switzerland and released through the Intercosmos Council.

Venera 15 concluded its radar imaging of the northern hemisphere of Venus on 10 July 1984. By this stage, 120 million km^2 had been mapped between 24°N and 33°N to a resolution of $\pm$2 km. The images revealed ridges, craters, folds and breaks in the planet's crust.

The double flight began in early June 1983 and, after being inserted into Venus orbit, operations by both craft began on 11 November 1983. Both entered orbits of 1000 by 65,000 km, period 24 hr, inclination 87°. According to

Beta Regio on Venus as observed by the Arecibo radar system in Puerto Rico. Resolution is about 2 km, similar to that achieved by the Soviet orbiters. The bright areas appear to be shield volcanoes and lava flows. *Arecibo Observatory*



Kovtunenko, the orbiters were based on the standard Venera bus, as used since Venera 9. The radar imaging and other experiments took the place of the descent module. The tanks of the bus had to be lengthened by 1 m to accommodate the extra propellant required for the insertion manoeuvre. The diameter of the parabolic antenna was widended by 1 m and, in order to transmit the images, downlink volume was increased no less than 30 times compared to the earlier flights. The craft each carried a scientific payload of four experiments weighing 370 kg: Side-looking radar (300 kg); 'Omega' radiometric system (25 kg); 'Fourier' spectrometer (35 kg) and Radio occultation experiment (10 kg).

There were five main objectives. First, the spacecraft would compile a radar map of the planet's surface. Second, they would obtain a surface profile with the 1 m diameter radar altimeter antennae. Third, they would compile a surface thermal map. Fourth, the 'Fourier' spectrometer would investigate the infrared spectrum. Finally, they would study the ionosphere and the near-solar plamsa. Data are routed through the 'On-board Complex Radiotechnical System,' which includes a common transceiver that can be linked either with the altimeter antenna or the Side Looking Radar. The SLR operates at 10° from the orbital plane.

Once the process of radar imaging was completed in July 1984, detailed processing of the data began. Two major thermal anomalies were found. The first, between 17°N and 32°N and between 281°E and 288°E, had a radio brightness of 150 to 200 lower than the surrounding terrain. The second, between 0° and 15°N and 60°E to 70°E, is 250 K lower, and coincides with the Maxwell Mountains.

As a result of the 1000 spectrograms produced, it was found that clouds in the polar regions were 5-8 km lower than at the equator. The atmosphere was found to consist of regular formations between 47 and 70 km altitude. Between the equator and 45°N, temperature, pressure and rate of turbulence were stable: north of 70°N, temperature decreased according to surface altitude.

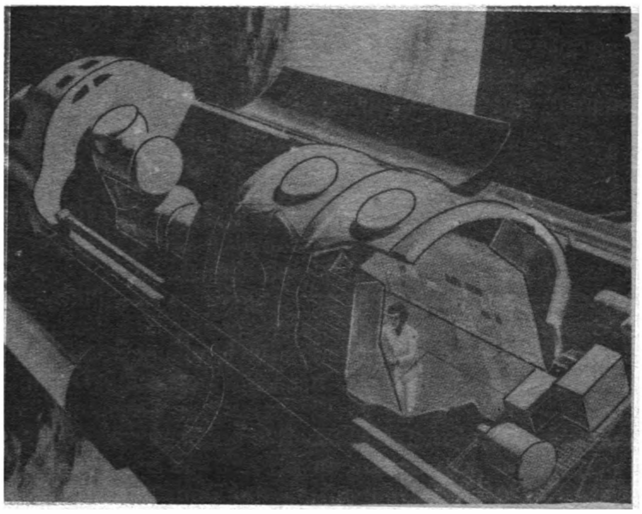
It is not clear whether Venera 15 and 16 have now fully accomplished their missions though the bulk of their work would appear to be over. The announcement of these details and results does, at least, break a silence on two relatively poorly publicised missions.

WEATHER SATELLITE TO PLANETS?

Under a NASA/RCA study of the applicability of existing Earth satellites for future planetary and lunar missions, the Tiros/DMSP satellites were seen as the best choice, writes Nicholas Steggall. Dr. Ronald Maehl of RCA Astro-Electronics said that DMSP (the US Military weather satellite) 'clearly provides the best candidate for a low-cost satellite for use in proposed NASA missions, including the Mars Geoscience Climatology Orbiter, Lunar Geoscience Orbiter and the Near Earth Asteroid Rendezvous Mission.'

Existing Earth-orbiting satellite technology could be cost effective for unmanned missions ranging from Venus through to the inner portion of the asteroid belt, although they probably would not be practicable for missions further in towards Mercury or past the centre of the asteroid belt.

The Tiros/DMSP choice is based on its ability to carry remote sensing instruments with a high degree of pointing accuracy and to operate autonomously for long periods using a sophisticated on-board computer for command and data-handling functions, and guidance and control.



The Spacelab J mission is currently scheduled for January-February 1988. *NASDA*

JAPANESE SPACELAB

The 'First Material Processing Test' by the National Space Development Agency of Japan is scheduled to be flown aboard the seven-day Spacelab J mission with a planned launch date of 27 January 1988, writes Nicholas Steggall. The FMPT will consist of three Spacelab double racks plus a Shuttle mid-deck refrigerator with some storage provisions in the form of seven overhead storage containers and five mid-deck modular lockers.

The crew for the Spacelab J will consist of six, including the commander, pilot, two mission specialists and two payload specialists. One of the latter will be Japanese, chosen from two or three candidates.

The FMPT objectives are:

1. to perform basic and applied experiments on material processing and life sciences in the microgravity environment of space.
2. to include a Japanese Payload Specialist in the Shuttle crew to perform experiments.
3. to establish the basic technology for developing a Shuttle on-board experiment system and Payload Specialist selection training and health management technology.

BLOOD EXPERIMENT IN ORBIT

An Australian experiment to investigate the effects of different diseases on red blood cell aggregation and blood viscosity was carried aboard the military Shuttle 51C mission in January. It was originally to have been aboard flight 51A last November but was withdrawn because of lack of space.

Called 'Aggregation of Red Blood Cells,' the experiment was designed to provide information on the rate of formation and the internal structure of red cells and on the thickness of whole blood at high and low flow rates.

Blood samples from both healthy donors and people with different medical conditions, such as heart disease, hypertension, diabetes and cancer, were used. The results are being compared with those from a simultaneous ground-based version. A primary objective is to determine if information obtained in microgravity can be used in new diagnostic tests or the improvement of existing ones.

ASTRONOMY

BROWN DWARF DETECTED

Astronomers have found evidence for a massive planet in orbit around another star. This new planet (or, more accurately, 'brown star') might hold the key to two of the most fundamental problems in astronomy today: the existence of other planetary systems such as our own and the nature of the suspected 'missing mass' in the Universe.

Donald McCarthy and Frank Low, both of Steward Observatory at the University of Arizona in Tucson, and Ronald Probst of NOAO, also in Tucson, made the discovery using the 4 m Mayall Telescope at NOAO's Kitt Peak National Observatory last May and the 2.3 m telescope at UA's Steward Observatory in June and July.

The object was detected with infrared 'speckle interferometry' while observing Van Biesbroeck 8, a star 21 light-years from Earth and in the constellation Ophiuchus. It is the first time that such a body has been 'seen by its own light,' though other astronomers inferred their existence from measuring the wobbles of certain stars across the sky. McCarthy and his colleagues designated the object as VB 8B and believe it to be gaseous, resembling Jupiter in appearance.

HUBBLE ARRAYS TESTED

British Aerospace have successfully completed a series of Solar Cell Blanket Deployment tests on the flight solar array for the NASA/ESA Hubble Space Telescope, due for launch in mid-1986.

The first of two wings of the 4.4 kW array, together with a total of 48,760 cells, were extended on large water tables to prove the double roll-out electrical/mechanical system that will unroll the 33 m^2 arrays in space. Unlike any other solar arrays made for space applications, they must be capable of operating unattended in space for five years and then be replaceable in orbit or returned to Earth for maintenance. The array technology developed by BAe for this programme is applicable to future advanced space missions. These could involve, for example, other very large astronomical observatories or elements of the Space Station that will be in orbit in the 1990's and beyond.

SATELLITES

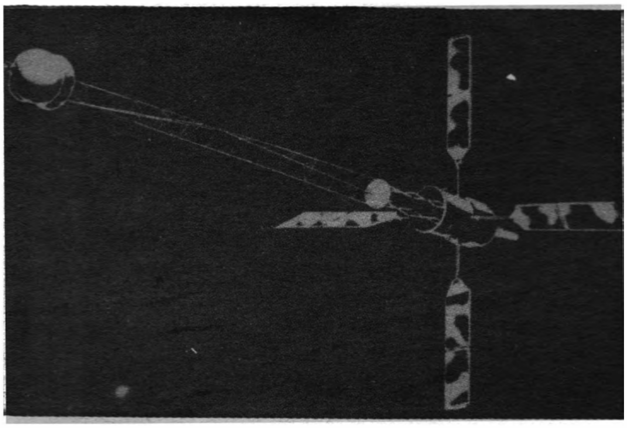
NOVA IN SERVICE

The US Navy's second Nova navigation satellite came into service in January as an aid to shipping. The satellite, launched on 12 October 1984, is the second of three built by RCA Astro-Electronics to operate as part of the Transit system that serves as a worldwide navigation aid.

Transit satellites have been used for all-weather global navigation since 1964, when they were put into service in their original role as an aid to submarines.

Novas have a number of improvements over the earlier Transits. They include a stronger transmitter, increased computer memory, improved reference clock stability and a capability to compensate for orbit disturbances.

The satellites weigh 169 kg at launch and orbit at an altitude of 960 km. With their 8 m gravity gradient booms extended, they are about 10 m long. Power is provided by four solar panels and a 12 amp-hr, nickel cadmium battery. The solar panels keep the battery charged for use when the satellite is in Earth's shadow.



The second NOVA navigational satellite is now in service. The first was launched on 14 May 1981. *RCA*

MARECS IN OPERATION

A new Inmarsat satellite began operations in early January, boosting capacity for maritime communications in the Pacific Ocean area. Marecs B2, owned by ESA and leased to the 41 member-country International Maritime Satellite Organization (Inmarsat), was brought into operation at exactly 0700 GMT on 8 January.

'We have been experiencing some periods of heavy loading on the existing Pacific Ocean satellite so we anticipate there may be a surge in demand as users take advantage of the improvement in service, particularly with obtaining first-time connections,' Inmarsat's Director General Olof Lundberg said. As well as telephony, Inmarsat also provides telex, medium and high-speed data and facsimile services for the world's maritime community. Inmarsat's previous Pacific satellite had a total capacity equivalent to only about 10 simultaneous telephone calls, while the new Marecs can handle the equivalent of more than 50 telephone calls at once.

Marecs B2, was launched by an Ariane 3 rocket on 9 November 1984 from Kourou, French Guiana, and then underwent orbital refinements and tests. The two Pacific satellites were located very closely (Marecs B2 in geostationary orbit at 177.5° E and Marisat at 176.5° E) to make the change of satellite as simple as possible for the hundreds of vessels using ship Earth stations in the Pacific area.

CANADIAN PROJECTS

A contract worth $14.4 million for the design and development of the Radarsat satellite system has been awarded to the Canadian Spar Aerospace company. Scheduled for launch into a polar orbit in 1990, Radarsat will survey Canada's mineral, forest and agricultural resources, as well as the ice packs in northern waters. By means of synthetic aperture radar (an imaging system immune to weather disturbances), the spacecraft will return valuable information for resource extraction, economic data and shipping. The project will be centred at Spar's Satellite and Aerospace Systems Division in Quebec.

Spar will also undertake two other projects. The company's Remote Manipulator Systems Division will develop

and manufacture a $2.5 million space vision system to enhance the performance of the Space Shuttle's robot arm. Using sophisticated computer program, it will afford more accurate readings of a satellite's range, velocity, attitude and position. Target pattern dots photographed by the existing wrist TV camera on the robot arm will be precisely measured by the system, a process known as photogrammetry. The Division will also conduct a $1.6 million study related to the technology requirements and benefits to Canada of participation in the US Space Station programme.

OTHER NEWS

LABORATORY AGREEMENT

A Memorandum of Understanding signed by NASA and Rockwell International in January could allow future flights of the company's materials processing laboratory. Under the six months agreement, Rockwell will develop an industrial space processing programme in which the company's modular, zero-gravity laboratory would be made available to research institutions and commercial firms. Experiment packages would involve a range of processing applications, including liquid chemistry, fluid physics, thermodynamics, crystal growth and biological cell culturing.

The laboratory is designed to be housed in the Shuttle's mid-deck area. It is about the size of a domestic TV set and is the first industrially-developed laboratory to be made available to the scientific community and commercial firms for basic products research in low-Earth orbit. It was successfully operated last summer on Shuttle mission 41D when a single indium crystal was grown with a lattice structure originating from a crystal seed. It can heat, cool, expose to vacuum and manipulate experiment samples that might be gaseous, liquid or solid. Samples can be mixed and stirred in containers or be processed semi-containerless in the 'float zone mode.' Samples can be removed and changed during a mission and a camera installed to record sample behaviour and data displays.

UK SPACE FINALISTS

The six schools who won places in the final of the British 'Experiment in Space' competition were announced in late January. The competition proved to be an unqualified success for Kent, which has provided three of the successful entries, including two from girls' schools. The six were Dr. Challoner's Grammar School (Amersham, Bucks), Ashford School for Girls (Ashford, Kent), Matthew Humberstone Comprehensive School (Cleethorpes), Fraserburgh Academy (Fraserburgh, Grampian), Hayes School (Hayes, Kent) and the Ursuline Convent School (Margate, Kent).

The schools then went forward to the final early this month (March) knowing that the winners will be invited to build their experiment to orbit the Earth aboard a Shuttle mission early next year. It is hoped that it will be on board the same Shuttle as Britain's first astronaut, together with the UK Skynet 4 satellite.

The competition, which ran from May until mid-October last year, attracted many imaginative entries and Independent Television News, the sponsors, have been delighted at the response. 'It has been a worthwhile and most rewarding project,' said ITN Editor and Chief Executive, David Nicholas.

MILESTONES

December 1984

27 NASA Administrator James Beggs approves the option of including a flyby of asteroid 29 Amphitrite in Dec. 1986 by Galileo on the way to Jupiter. The actual decision will be made after launch in May 1986.

January 1985

5 Shuttle *Discovery* is moved to the launch pad for Mission 51C on 23rd carrying a military payload. No general public viewing will be allowed.

7 TV views of the Soviet Vega Halley probe launches show the D-1-E rocket to carry six strap-on boosters, long suspected by western observers.

8 The Marecs B2 maritime communications satellite begins operations over the Pacific region. It was launched on 9 November 1984 by Ariane 3.

8 NASA and the University of Arizona have agreed to develop an astrometric telescope to be mounted on the Space Station in the mid-1990's to search for planetary systems around other stars.

8 The 138 kg Japanese MS-T5 probe is launched by a Mu-3SII vehicle as a test for the Planet-A Halley's comet probe (launch: 14 August). It will venture no closer than 3 million km to the comet and carries no cameras.

14 The first Shuttle launch from Vandenberg AFB in California has been delayed from 15 October to February 1986. Preparing the site for its first launch is taking longer than expected.

15 Six Soviet satellites, Cosmos 1617-1622, are orbited by a single launch vehicle.

16 The West German Cabinet has approved participation in the Ariane 5 and Columbus programmes but not the French-proposed Hermes mini-shuttle.

17 NASA officially assigns US Senator Jake Garn as a passenger aboard Shuttle flight 51E, due for launch 20 February.

18 The US Navy's second Nova navigational satellite comes into service. It was launched on 12 October 1984.

23 Shuttle mission 51C is delayed for a day because cold weather was allowing ice to form on the vehicle.

24 Shuttle 51C with astronauts Tom Mattingley, Loren Shriver, James Buchli, Ellison Onizuka and Gary Payton (USAF astronaut) is launched carrying a military payload aboard *Discovery*.

27 Shuttle 51C lands at KSC after an apparently successful Dept. of Defense mission.

28 ESA has approved studies of a semi-reusable twin-booster cryogenic launcher to succeed the Ariane family next century.

29 Britain is to establish a National Space Centre, probably at Farnborough. The UK will also contribute £7 M to ESA's £50 M Columbus space station studies over the next two years.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

DREAMS AND FANTASIES

The Prospects for Space

By Dr. Bob Parkinson

The author, Study Manager for Space Station studies at British Aerospace, provides a personal view of the development of Man's ventures into space, from the visionary 1950's to the more pragmatic 1980's.

Introduction

In a very real sense, my generation of Space Engineers, in our teens in the 1950's, were programmed by the visions of Wernher von Braun, Arthur C. Clarke, Chesley Bonestell and R.A. Smith. We knew what had to be done. First we would have to develop large, re-usable launch vehicles capable of ferrying tens of tons into low Earth orbit. We would then construct a permanent, manned Space Station to act as a base for our onward activity. From thence we would mount missions to the Moon, set up temporary or permanent encampments on our natural satellite, move on to Mars, and later - successively - to the exploration of the other planets of the Solar System. Someday, we knew, there would be permanent colonies in the sky and men who knew only of the mother planet Earth as a star in the darkness.

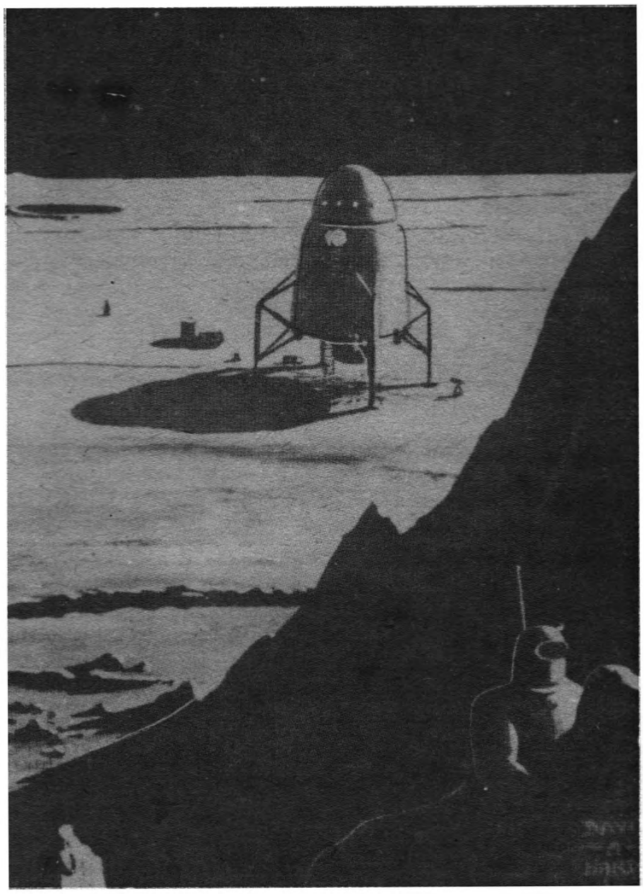
Those were the dreams. In some respects the advent of Apollo and the immediate reaching for the Moon came out of sequence. The 'fantasy' in the title is the belief that, somehow, because of the excitement inherent in that vision, such things had some sort of inevitability about them. We have become a little more sophisticated since we discovered how expensive such enterprises were, and suffered a few budget cuts. But still there are many wild proposals that seek to harness apparently limitless funds to so-called 'commercial' space enterprises as a way of opening up space. Colonies in space, powersats, vast quantities of space manufactured materials: we need to know whether these are real possibilities or new fantasies.

Currently, the most important commercial success in space has been that of communications satellites. At peak period, a trans-Atlantic phone call costs about 75p a minute. Multiply that by eight hours a day, 260 days a year, and a total of seven years for the life of a satellite and a fairly modest 6000 voice-channels for a satellite. The revenue works out at about $4979 million. Admittedly, some of that revenue has to pay what is called 'ground segment' - the receiving stations and the local telephone network itself, but British Aerospace would arrange to build, launch and insure a satellite of that size for about $90 million - or just 1.8% of the total revenue!

Things may never be that good again, but it does help to explain why so many companies are in the communications satellite business and why Europe decided to optimise the Ariane launcher for geosynchronous orbit.

The Space Station

The Space Station is seen as the next major enterprise. It will provide a permanent laboratory in the sky, serve



The BIS spaceship on the Moon, a 1956 concept by David Hardy.
©D.A. Hardy (1956)

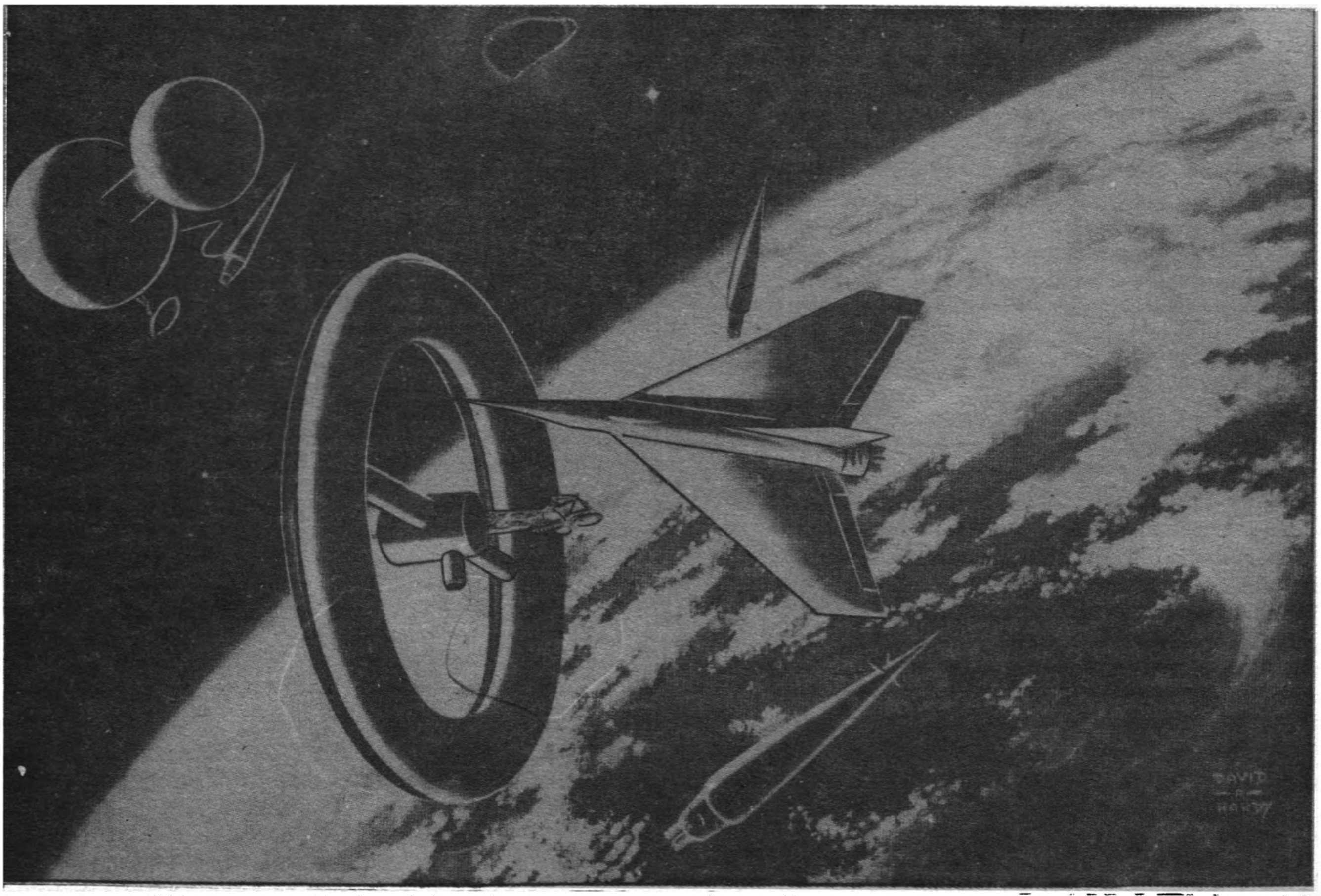
as a transport and construction 'node' between the Shuttle and destinations further out and have a rôle in servicing satellites in orbit. Many hopes are being placed on its ability to encourage 'commercial' users who will exploit the unique, low-gravity environment to create new products. Publicity is being given to the McDonnell-Douglas/Johnson & Johnson work on pharmaceutical production, but other possibilities include special semiconductor materials and new alloys. Semiconductor materials in the form of large, flaw-free crystals of gallium arsenide might well be an attractive product.

Look at the economics. First, estimate how much it will cost to rent space on the Space Station. NASA has not yet issued a pricing policy but Table 1 is an optimistic projection of the running costs and income. Much will depend on the size of the 'army on the ground,' and in practice the costs could be two or three times as much. If they *are*, the Space Station will be even less attractive

Table 1. Economics of the Space Station

Expenses	
Maintenance	$343 M p.a.
Shuttle flights	$318 M p.a.
Devpt. surcharge	$132 M p.a.
	$793 M p.a.
Income	
14,016 m-hr astronaut time	$196 M p.a.
External berths $8.6 M/qtr	$275 M p.a.
Internal space $1.0 M/qtr	$322 M p.a.
	$793 M p.a.

This article is based on a presentation by the author at Space '84, Brighton, 16-18 November 1984. Please note that US billions are used throughout (= 1000 million).



A collection of 1950's proposals. Von Braun's 'wheel' space station, Arthur Clarke's 'Dumb-Bell' deep space ship and R.A. Smith's ferries and fuel tankers. *© D.A. Hardy (1956)*

to commercial users. Fortunately, NASA seems to be adopting the idea that the Space Station will have to operate as an autonomous facility, with the minimum of ground support, so there are grounds for optimism.

The Space Station will be serviced at 90 day intervals, so this is the natural 'rent' period. Now look at the costs that a user might incur, as in Table 2. There are the costs of the launch of the material to be processed, rent of the furnace and use of astronaut time. For the 150 kg of material assumed in Table 2 the cost of space processed material works out to about \$21,000/kg. By comparison, the current price of useful, sliced Gallium Arsenide crystal produced on the ground is about \$30,000/kg. The costs derived here are sensitive to a number of factors, particularly to the quantity of material being processed. But the table illustrates the point. It may be economic to make things on the Space Station but the margins are not like those associated with communications satellites.

Lunar Materials

The Space Station is expected to have a rôle to play in the older business of transport to geosynchronous orbit. It is planned to use it as a permanent base for a high performance Orbital Transfer Vehicle (OTV), which will provide transport between the Station and geosynchronous orbit. The Shuttle will bring up satellites and propellant to the Station, to be assembled as cargo and propellant for the OTV which will then boost them into the higher orbit. Its job done, the OTV will return to the Space Station, probably using 'aerobraking' to shed velocity on its final approach.

The OTV will use oxygen and hydrogen as propellants. It may get them by scavenging from the Shuttle External Tank or by electrolysing water brought up as 'ballast' in the Shuttle. One possibility is to manufacture the liquid oxygen from Moonrock and to ship it back to the Space Station rather than up from the Earth. By using aerobraking to slow the transport OTV as it approaches the Earth, it is possible to end up with several times more liquid oxygen back in Earth orbit than the liquid hydrogen needed to lift from Earth to drive the system.

Here is an opening for commercial exploitation for lunar materials. But how real is it? Without knowing too much about the detailed engineering, we can get a first estimate of the cost of developing and building a lunar liquid oxygen plant of around \$3 billion (Table 3). It is then relatively easy to calculate that the cost of operations, plant maintenance and recovering the initial investment is in the order of \$780 million per year - or close to the 'optimistic' cost of maintaining the initial Space Station. To be worthwhile, therefore, the lunar liquid oxygen plant must deliver more liquid oxygen to low Earth orbit than could be lifted up for the same price from the Earth by Shuttle launches. The resultant 270 tonnes/year is within the capabilities of the system but it represents a transport rate to geosynchronous orbit of about 122 tonnes of satellite per

Table 2. Cost of Orbital Manufacture

Launch 150 kg of raw material in standard package	\$ 1.4 M
Rent furnace facility on Space Station for 90 days	\$ 1.2 M
40 m-hr astronaut time	\$ 0.6 M
Total	\$ 3.2 M
Space processed material	\$21,000/kg
c.f.Ground produced GaAs	\$30,000/kg

Table 3. Economics of Lunar Liquid Oxygen

Cost of liquid oxygen plant, transport infrastructure and placement	$ 3000 M
Cost of maintenance operations and investment recovery	$ 780 M/yr

Equivalent to 11 Shuttle launches p.a. = 270 tonnes liquid oxygen/year

Would transport 122 tonnes of satellites into geosychronous orbit annually.

Table 4. Economics of Powersats

A 10 GW Powersat has a mass of 57,000 tonnes.

At 4.83 p/kW-hr, total income from generated power $5.2 billion/year.

Assume 25% costs in space segment, interest on investment and maintenance charges 20%.

Space segment maximum investment value = $6.5 b

Equivalent launch cost into low Earth orbit = $28/kg.

Table 5. How Cheaply Can You Launch?

(10 t payload/launch)

Amortize vehicle over 500 launches	$ 0.27 M
Spaces and maintenance	$ 0.21 M
Vehicle insurance	$ 0.23 M
Propellant	$ 0.29 M
Launch preparations and flight support	$ 0.38 M
Facility maintenance	$ 0.14 M
	$ 1.52 M

Launch cost $152/kg
No recovery of development costs

Table 6. Programme Costs

Apollo	$40 B
Space Shuttle	$14-39 B
Space Station	$ 8-20 B

(1983 values)

Table 7. What Can Be Bought for $40 Billion?

Second generation Shuttle	$ 19 B
Lunar Base	$ 9 B
Manned Mars Mission	$ 7 B
10 MW Nuclear-Electric Stage Gas-Core Nuclear Engine	$ 4 B
	$ 40 B

year. This is a long way short of even the most optimistic estimates for the requirements for communiations satellites.

Interestingly, the transport masses involved are not excessive if we become interested in manned operations. A 1½ tonne satellite is a big satellite, but it is a very small manned capsule. A resumption in lunar exploration or initiation of manned missions to Mars would probably be sufficient justification for a lunar liquid oxygen plant.

Powersats

One proposal that would involve transporting very large quantities of material to geosynchronous orbit is the Powersat. Power satellites would generate very large quantities of electricity in orbit from vast solar arrays and then transmit the power down to Earth as a tight microwave beam to receiving antennae ('rectennae') on the ground for input into the power supply grid. Such Powersats would be huge, perhaps 15 km along a side. One estimate is that a 10 gigawatt version would have a mass of 57,000 tonnes.

The economic viability of Powersats depends on launch costs. Just as with communications satellites we can calculate the total income made possible by a 10 GW Powersat. At 4.83p/ kW-hr the income is about $5.2 billion per year. Making due allowance for ground segment costs and the need to maintain and operate the Powersat itself, that implies a value for the initial space segment investment of about $6.5 billion. It could be a little more but it is unlikely to be twice as much. Knowing the relative transport costs for geosynchronous and low Earth orbit (a factor of four) this is equivalent to a launch cost into low Earth orbit of about $28/kg.

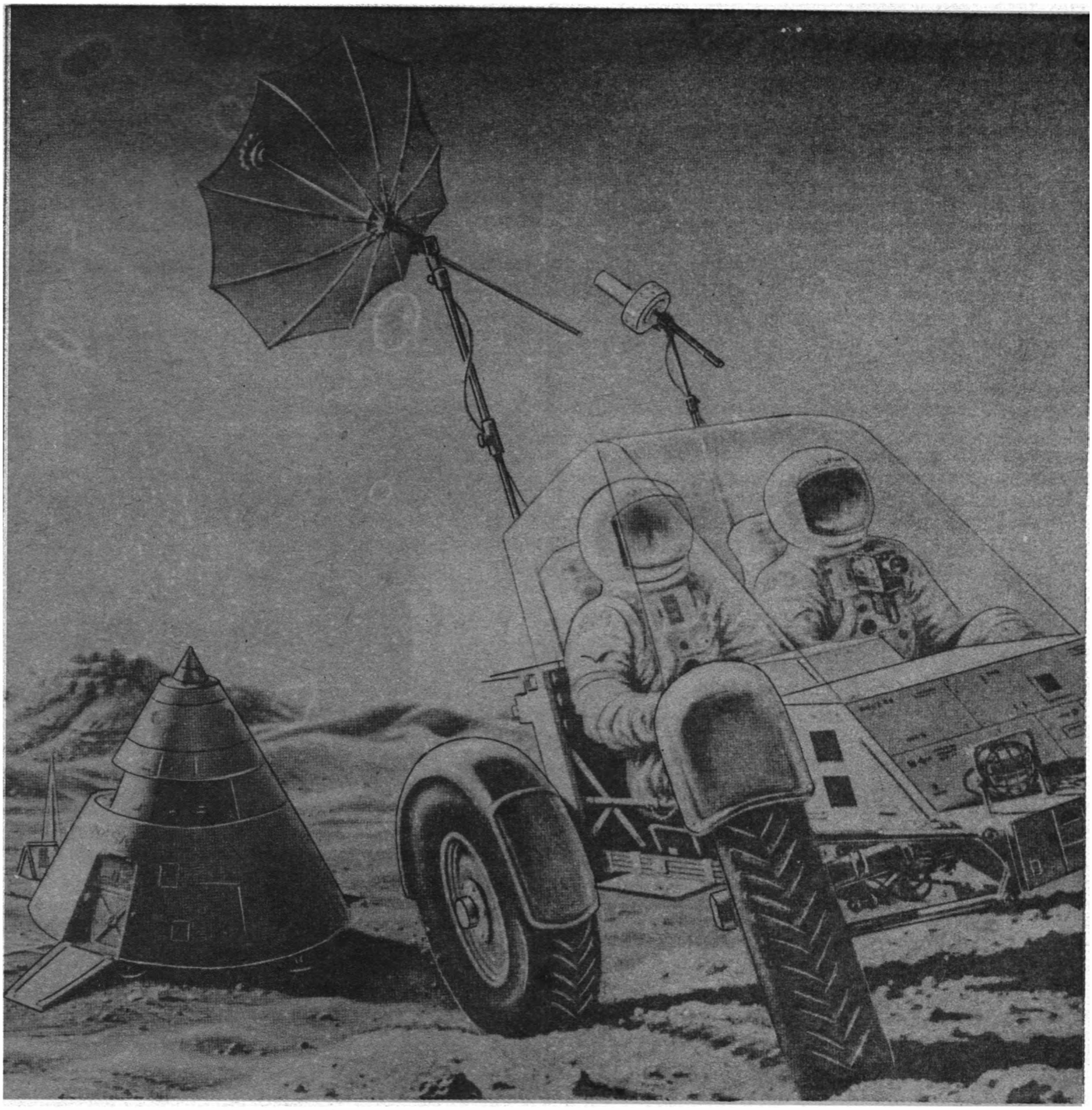
The current transport cost into low Earth orbit with the Shuttle is $3000/kg. This, therefore, represents a very considerable reduction. Even allowing for the fact that we might make gains in orbital transport costs (by using lunar liquid oxygen, for instance), it is apparent that we need to reduce Earth-to-orbit launch costs dramatically.

How cheaply could we launch into low Earth orbit? At British Aerospace recently we undertook a study, looking at the economics of 35 different launch vehicle configurations to find the shape of a launcher suitable for the 21st century. Part of the answer depends on how much the launcher can be used. Development costs are a substantial part of total costs; the most economic launch configurations only gain cheap launch costs at the expense of substantial developments. Out of this study, however, was born the Hotol concept, using a degree of air-breathing during the early phases of flight to produce a launch vehicle with single-stage-to-orbit capabilities and low operational costs.

Table 5 is an estimate of how low launch costs might be made in the 21st century. It makes optimistic estimates for the number of launches an individual airframe might fly (500 against the Shuttle's 125) and optimistic assumptions about the size of the turn-round operation needed on the ground (Shuttle needs 5000 people). It also assumes no recovery of development costs. Even with these optimistic assumptions the launch cost is about $150/kg.

It is worth noting, however, that the total launch cost in Table 5 is only $1.5 million per launch, in comparison with a Shuttle charge of $71 million. There is no doubt that such a low launch cost would very substantially encourage new users of space.

New commercial users by themselves, however, may not be sufficient to generate the demand for improved, low cost launch systems such as Hotol. What is demanded is some commitment to the future - a certain vision of the possibilities such as mentioned at the start of this



Manned exploration of Mars is a dream of the 1950's. © D.A. Hardy

article.

Twenty five years ago that vision, whatever the true motives, generated the Apollo programme and liberated (at current prices) $40 billion for space activity in the process. Table 6 shows a comparison of the total project costs expected from Apollo, the Space Shuttle (the numbers represent initial building and operating costs to the end of life) and the Space Station. While the Space Station is seen as a large, prestige project it is apparent that horizons have shrunk since the 1960's. Suppose that somehow, again, the world space community were capable of liberating $40 billion for new projects after the Space Station. What could be bought? A list of possibilities is given in Table 7.

By the beginning of the 21st century the world will need a new launcher. The big, American, second-generation Shuttle may cost as much as $19 billion to build. The smaller Hotol would be very much cheaper. Next comes the cost of setting up a permanent Lunar Base and mounting a manned mission to Mars. With the Space Station and an effective launcher, both are not then too expensive enterprises - no more difficult than the Space Station. Finally, the options for really high performance, inter-orbit and interplanetary propulsion - 10 MW nuclear-electric, gas core fission or fusion propulsion - are cheaper still. By the estimates from NASA's 1975 study of future prospects in space, a really powerful interplanetary propulsion system would cost 'only' $4 to $5 billion. Such a system would truly open up the Solar System to mankind.

That is how close we are to an interplanetary culture: about the cost of Apollo!

There is probably no magic wand that will suddenly open up space to Mankind by natural events. Each significant project will have to be fought for on familiar grounds - competing for budgets, serving political ends, demonstrating its service to a 'need.' At any time only some of those enterprises will be credible and the space community may damage itself by espousing too many wild ideas too soon. But the gap that separates us from the dreams of the 1950's is narrowing.

SPACE SCIENCE IN EUROPE

ESA's *Space Science Horizon 2000* report, published last summer, presents European thinking on projects for the next two decades. Clive Simpson summarises the report below.

Introduction

Exploration of space is one of the greatest adventures of mankind. As a result of rapid advances in the past 25 years we have witnessed a dramatic change in our perception of the Universe.

Such a widening of the horizon in a relatively short time is almost unprecedented in human history, with the exception perhaps of the time of Galileo when the telescope provided a significant step forward in the technology of the period.

In a similar way, advances in technology in modern times have provided the basis for the discovery of a completely new set of phenomena that have radically modified our understanding of problems such as the formation and evolution of galaxies and the formation of stars and the Solar System.

Space science has played a key role in advancing this knowledge, not only through direct exploration of the Solar System but also because satellites have permitted the systematic investigation of the Universe in parts of the electromagnetic spectrum blocked off from Earth by the atmosphere.

A surprising picture of the Universe has emerged, dominated by cataclysmic events, explosions and shocks with releases of immense amounts of energy. The old serene Universe of Aristotle, populated by perfect objects moving in silent harmony, is no more.

Space science is thus an essential element in the development of science today. Its impact extends well beyond the frontiers of astronomy and of the Solar System into the domains of fundamental physics, plasma physics, atomic physics and Earth sciences.

The Future

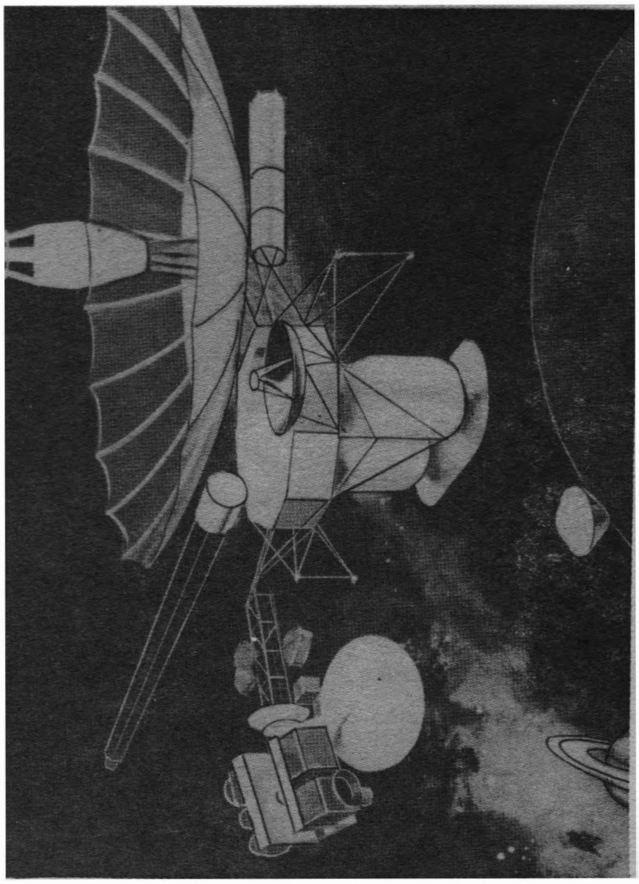
The new European programme represents a new approach to the planning of scientific activities in the European Space Agency (ESA). Instead of defining scientific missions on a case-by-case basis the plan identifies certain priorities that will act as 'cornerstones.'

It aims to strike a balance between specific scientific projects and incorporate sufficient flexibility to benefit from technological progress.

The study that led to the proposed long term plan was initiated in September 1983 and was coordinated by a survey committee composed of scientists from different areas of fundamental science. The results have now been published in an ESA report entitled *Space Science Horizon 2000*.

Chairman of the survey committee, Johan Bleeker, says in his introduction, 'The main thrusts in a 20 year programme need to be indentified now in order to accommodate appropriate technological developments and to indicate to the scientific community at large what Europe has to offer in terms of scientific projects and missions in space.'

There was a massive response from the European community to the call for mission concepts and in the summer of 1984 the results of discussions were analysed



Cassini, a Saturn orbiter/Titan probe in cooperation with NASA, is a possibility for a European project. *NASA/JPL*

in a three day meeting in Venice during which a coherent overall programme for European space science over the next 15 to 20 years was built up.

The programme, founded on four major cornerstones achieves, through a relatively modest increase in funding, a quantum jump in scientific significance and offers the capability of frontline research to the European community.

It gives Europe the means of being an equal partner in the worldwide scene of space science as well as honouring its cultural heritage and scientific tradition.

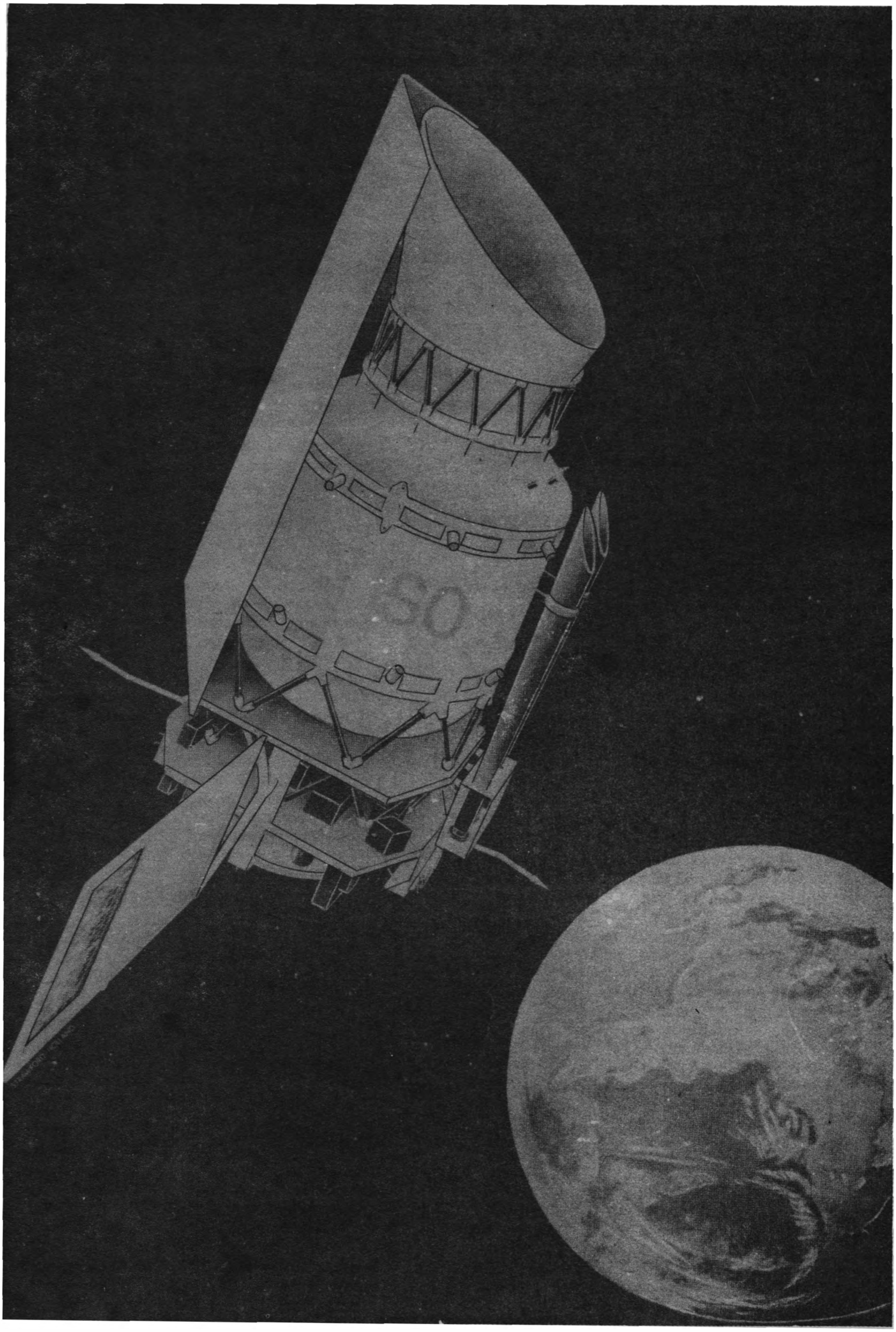
The report stresses that any independent European long term programme should obey the following criteria:

1. scientific standard: cultural heritage and scientific tradition demand Europe's scientific goals to be set at the highest standard.
2. a suitable mix of large and smaller projects.
3. flexibility and versatility to match scientific evolution.
4. give continuity of efforts to scientific institutes and industry.
5. have a high technological content.
6. remain within realistic budgetary limits.
7. maintain a proper balance between purely European and cooperative projects with other agencies.

Space Science

The report recognises that space science has a crucial role to play in the development of many areas of science. For instance, space techniques now provide a powerful means of studying our planet. Solar System science also

Facing page: the Infrared Astronomical Observatory (ISO) will extend the work performed by the Infrared Astronomical Satellite (IRAS), which ceased operations in November 1983. *ESA*



relies heavily on space research techniques which now allow us to use satellites to explore celestial bodies and their environment.

There is also a need for more sophisticated planetary studies with the aid of orbiters (for Mercury, Venus, Mars and Saturn) and multiple rendezvous missions with small bodies (asteroids and comets). The return of pristine material will constitute a major theme in future planetary science.

Asteroidal samples would lead to a direct comparison with meteoric material at the high accuracy levels required for classifying the material.

A drill core returned from a comet, consisting of ice and dust, would be of the highest scientific interest. The cometary sample might contain not only unaltered pristine Solar System material but possible interstellar and stellar material, providing a valuable insight in the physics and chemistry of star formation.

An analysis of current missions in solar and heliospheric physics shows that most scientific needs will not be adequately satisfied. A long range programme that would fill the gaps comprises five basic elements:

1. a free-flyer in Earth orbit: for ultra high spatial resolution, concerted imaging and spectrometry in many wavebands.
2. Lagrangian point L1 observatory: to address helioseismology, continuous measurements of the solar wind and corona.
3. continued use of the Lagrangian point on the Earth-Sun line as part of a synoptic array programme (SAP - an array of four spacecraft in solar orbits in the ecliptic plane).
4. heliosynchronous out-of-ecliptic mission for detailed study of the solar wind from a point close to the Sun, frequent coverage of the polar regions and a stereoscopic view.
5. solar probe: measurements of the corona down to regions where solar wind acceleration takes place, determination of the solar gravity field and testing of general relativity.

Planetary Science

Planetary science is almost entirely dependent on data acquired by space research during the past two decades; spacecraft from the US and USSR have explored the Solar System from Mercury to Saturn.

Missions have ranged from fly-bys to landers and orbital satellites. The emphasis on different planets has also varied: Mercury has been studied on only one fly-by mission, but there has been much more detailed exploration of our more immediate neighbours (Moon, Venus and Mars).

New mission concepts proposed for planetary science in Europe include the following:

- a Mars mission (e.g. the Kepler project)
- a lunar orbiter
- a comet fly-by mission
- multiple Venus orbiters.

A set of more advanced missions include:

- a Mercury orbiter
- a Saturn orbiter/Titan probe
- a multiple small bodies rendezvous mission (asteroids and comets)
- a comet nucleus sample return mission
- a Mars rover mission.

Space Astronomy

For centuries the only accessible wavelength for astronomical observations was a tiny slit in the electromagnetic spectrum - the visible wavelengths.

With the advent of the space age, the absorbing effects of the Earth's atmosphere could be entirely eliminated and the entire electromagnetic spectrum became accessible for observations.

Progress in modern astronomy and astrophysics requires, in many cases, a multispectral approach in which the correlation between observed characteristics in differing wavelengths provides the key. Only observation from space can accommodate such wide coverage, so it is clear that space astronomy forms a major component of present-day astronomical research.

Among the oustanding problems in modern astronomy and astrophysics are assessment of the formation and evolution of stars and planets, the origin of heavy elements, the nature of the galactic centre, origin of cosmic rays, and the formation and evolution of galaxies.

Study of these aspects requires spaceborne instrumentation since the important physical processes of many of these objects produce electromagnetic radiation outside the waveband accessible from the ground.

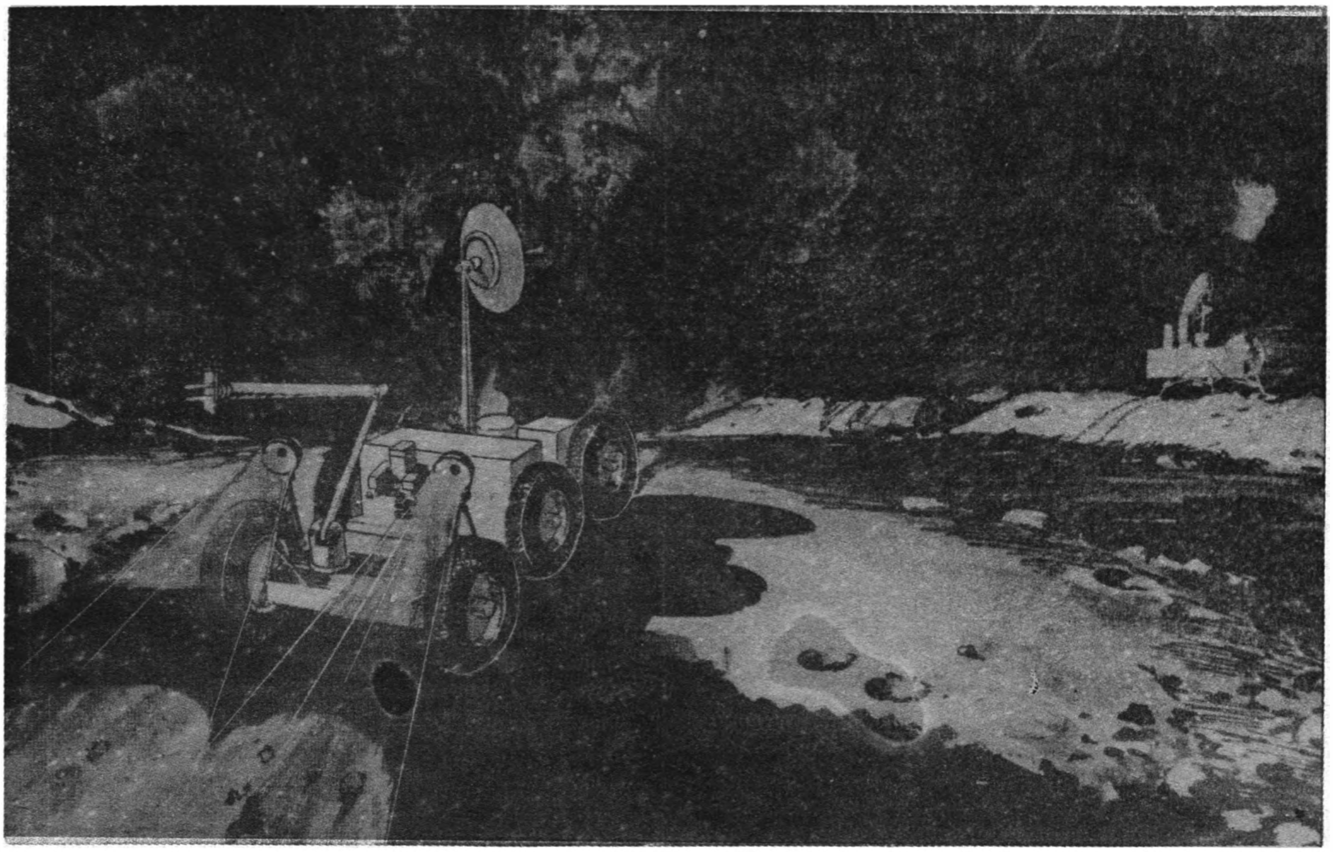
A Long Term Programme

The overall programme proposal is founded on four major cornerstones to be carried out up to the year 2004. Of the four, two are in Solar System sciences (planetary and the solar terrestrial programme) and the others in astronomy based on spectroscopy techniques, X-ray and heterodyne, the latter an effect produced by superimposing two waves of different frequency.

1. As discussed above, a major theme in future planetary science will be the return of primordial material from primitive bodies - the comets and asteroids - with Europe well placed to take a lead in this aspect of planetary exploration.
2. The solar terrestrial programme (STP) relies on extensive European experience in solar, heliospheric and space plasma physics. It consists of two medium-sized projects: an observatory and a multi-point space plasma physics mission.
3. An X-ray mission observatory, comprising multiple telescopes, will provide the required sensitivity to perform detailed spectral analysis of objects with low surface brightness. This is particularly important for studying the evolution of large and small scale structures in the Universe. The mission will be an ideal complement to NASA's AXAF mission.
4. The sub-millimetre domain is the last remaining gap to be explored in the electromagnetic spectrum. A major mission in this area is thus important and will be used to study many of the atomic and molecular transitions which provide a direct probe for studying the physics and chemistry of the cool Universe in the range 3-1000 K.

The four cornerstones and related major projects need to be indentified early because of the long lead time needed for implementation.

On a smaller scale a number of more conventional, medium-sized projects (in terms of cost) will be realised in the same-time frame. They include the already-approved Giotto, Ulysses, Space Telescope, Hipparcos and Infrared Space Observatory, plus about five others. These will come from within the following mission concepts: plan-



A Mars rover is a possibility for a European project.

Budget

The survey committee states that the future programme should be contained within a new budget envelope of about 200 MAU/year (in 1983/4 financial conditions), to be reached progressively between 1985 and 1991.

From a scientific viewpoint this new level will permit priority identification of the major projects at present required while retaining a reasonable number of small/medium sized projects.

Space Station

The programme outlined is not contingent on the existence of a Manned Space Station and could be carried out with existing means.

However, the report recognises the potential dramatic changes the Space Station might bring about and the survey committee endeavoured to analyse how this would benefit the proposed programme.

For instance, in-orbit repair and servicing capabilities will be beneficial to the long-living astronomical observaetary orbiters, solar telescopes, plasma and auroral projects, UV spectroscopy, stellar seismology and radio astronomy.

Such projects will be selected according to the ESA science programme normal procedure (an open competitive selection) through which the overall programme regains its required flexibility and the capability to meet the shifting needs of science.

On a still smaller scale, a number of projects are included which will respond to the need for frequent flight opportunities, quick reaction to missions of opportunity and minor participation in projects of other agencies.

Prominent in this class is a programme of utilisation of retrievable platforms such as Eureca, developed within the microgravity programme and suitably modified to meet the requirements of astronomical and solar physics payloads.

tories in low Earth orbit and the capability for in-orbit assembly of large structures might directly benefit the setting up of complex interplanetary spacecraft.

But the report also states that any use of Space Station services should be cost effective in relation to more conventional means and that the pace of station development should not affect the overall programme schedule.

Approval

In recommending approval for the programme together with an increase in the mandatory science budget for Solar System sciences and astronomy, the survey committee makes a number of conclusions, which include the following:

1. the programme permits a significant venture into the planetary area and includes the now indispensable astronomical observatories.
2. it has a high technological content and provides major challenges for innovative industrial developments.
3. it represents a quantum jump in Europe's ability to be at the forefront of all domains of space science with only a relatively modest budget increase.
4. it establishes Europe as a major party in the worldwide development of space science.

The programme presented in *Space Science Horizon 2000* is currently under discussion. Decisions on funding levels are expected during the course of 1985.

Editor's Note: We will be including a further article on this topic by Gordon Whitcomb, Head of the Future Programme Studies Office at ESA, in a forthcoming issue of *Spaceflight.*

AN APPRECIATION OF KRAFFT EHRICKE

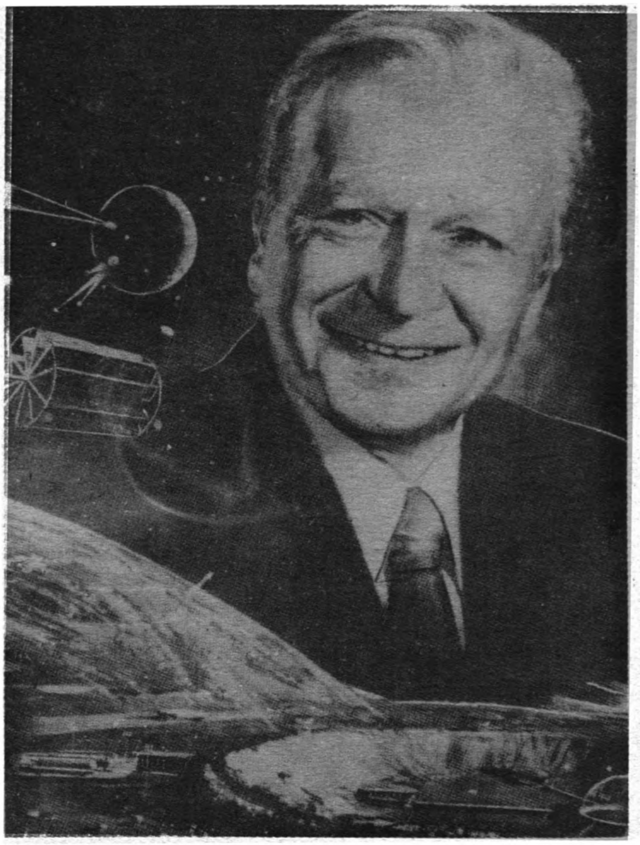
Many tributes have appeared following the death of Krafft Ehricke, a distinguished Fellow of the Society.

We can think of none more fitting than to use the words of one of his friends, in this case Deane Davis, writing to our Executive Secretary. Mr. Davis worked closely with Dr. Ehricke on the pioneering Centaur liquid oxygen/hydrogen upper stage and visited him shortly before his death. He recalls that, even though Krafft was visibly ill, work continued apace on a new book, *The Seventh Continent,* concerning the industrial development of the Moon:

"Krafft, a large table completely covered with piles of paper in a typical Ehricke mess, insisted that I went over the rationale and preliminary solutions for the transport system from the Moon to the orbiting base. As usual, I told him he was full of baloney - and the fight was on like in the old days (which is exactly why he asked me the questions in the first place). I know I overstayed my leave, Krafft was becoming visibly tired, but when he used to get that light in his eye and started delving sure-handedly through his mess for charts and graphs, there wasn't much one could do but have at it. Besides, also as usual, his basic logic was impeccable, it was just the mechanics of how he proposed to do it. I am, he so often told me, a mechanic.

"*The Seventh Continent*. Think about that for a moment because that is the essence of Ehricke in a nutshell. To him it was not just a 'snappy' phrase, it was a fact. Ehricke, in contrast to Wernher von Braun, never professed to be a 'star man' although he was canny enough to talk in that mode for public consumption. But Man, being what he is, will continue, at the behest of his genes, to drive into unexplored and unexploited lands. We are out of continents and the Moon is handy. The next question, to Krafft, was not 'when,' but 'how.'

"That belief in what Man would do, whether he thought of it or not, coloured everything he did from the beginning. (Never confuse his view of it as a 'mission' of man. He looked at it exactly as would an anthropologist of the strictest code. There was nothing of the metaphysical about Krafft). Even after Apollo, when, to my way of thinking, he went off half-cocked on the Shuttle, Krafft would calmly point out to me that even so, it was a step forward. We'd use it in its place, deviant though it was to a purist like me. And he would figure out a way to use it, notwithstanding the fact that he would rather see the effort expended on an orbiting space base. Krafft was a terribly impatient person day to day; in the long view he had the patience of a Job."



Dr. K.A. Ehricke,
24 March 1917 -
11 December 1984.

On 15 December 1984 a memorial service was held to honour Krafft's memory. Part of the tribute included the following:

We have lost a great scientist, a great humanitarian philosopher, a great human being, husband and father. We have gained, because he was here, a legacy of knowledge that is mandatory for the unlimited physical and mental growth of Mankind throughout an infinite future.

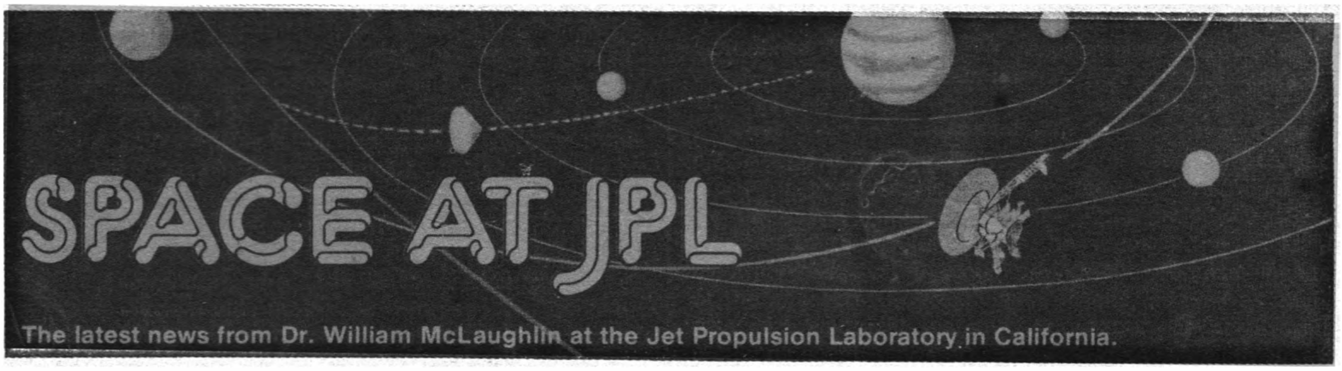
Krafft worked, and sacrificed, for more than 40 years to create and advance that knowledge. Now, he has entrusted all of us with the responsibility for applying it to the service of humanity, and to the preservation of Earth as "the garden of the Solar System."

DR. EHRICKE'S CAREER

Krafft Ehricke, one of the V2 pioneers, went to America after the Second World War to help launch the American space programme. He joined the Society in 1953 and, between 1956 and 1965, at General Dynamics-Convair in San Diego, California, he conceived and aided in the development of the Centaur upper stage - the first to use liquid hydrogen as fuel. The soundness of the work is demonstrated by the fact that Centaur is still in use and will see further service with the Space Shuttle. Another US project with which Dr. Ehricke was intimately connected was the use of Atlas as a space launcher, again still in demand. In 1965 he joined North American Aircraft where he held various senior positions in their Autonetics Division; from 1968 to 1976 he was Chief Scientist, Space Systems Division, North American/Rockwell.

In 1977, Dr. Ehricke created his own Space Global Co., a research and consulting firm, and was continuing work on developing his 'Extraterrestrial Imperative' theme. It was his belief that Mankind's destiny was to continue its historic expansion by basing industries in space. He was working on a new book, *The Seventh Continent,* at the time of his death, at the age of 67, last December.

We send our condolences to his widow, Ingeborg, and his three daughters.



TECHNOLOGY

A sample of some technologically-oriented activities at the Laboratory will be presented this month to provide not an overview but rather the flavour of such work. The subjects are: 1. nuclear-electric power for space; 2. a new breed of supercomputers; 3. an application of artificial intelligence, and 4. an example of how a successful space project (Viking) integrated new technology into its mission plan.

Dr. Lew Allen, the Director of JPL, spoke of the rôle of technology at a dinner meeting of the Caltech Management Club last November. He pointed out that JPL's highest priority missions, which make up the core programme of NASA (refer to the September-October 1983 and the May 1984 'Space at JPL'), are intentionally not dependent upon high technology. Thus, the proposed Mariner Mark II missions, the Planetary Observers and the Venus Radar Mapper mission can be low-cost endeavours because they rely upon proven technology and, in some cases, will even use hardware left over from past missions. In order to prepare for possible high-technology missions in NASA's augmented programme for the 1990's, Allen said that the Laboratory must maintain and strengthen its technological base. Examples of high-technology missions are a Mars sample return and the 'Starprobe' exploration of the Sun at close range.

Early in its history, JPL achieved success through its leadership in rocket technology. In the 1960's and 1970's, deep space communications, interplanetary navigation, synthetic aperture radar, charged-coupled devices (cameras) and a few other choice disciplines provided the technological muscle that resulted in 'the golden age of planetary exploration.'

Given the technological orientation of the 1980's, it is not surprising to see two of the three samples for this month's column drawn from the field of computer science. The third, nuclear-electric power, represents a concept that has had a long gestation period. What of the long-term future? Technological trends are notoriously difficult to forecast, but a good bet would be to keep an eye on the ubiquitous computer.

NUCLEAR-ELECTRIC POWER

Space missions require power to operate their various electrical and mechanical devices: radio transmitters, heaters, movable platforms, etc. At present, three methods are used. The first, the photovoltaic cell, is familiar through its use on solar panels for inner Solar System missions, such as Viking and Mariner Venus-Mercury. The second, the fuel cell, serviced the Apollo lunar flights. Finally, radioisotope thermoelectric generators (RTGs) convert heat from radioactive decay into electrical energy for the Voyager and Pioneer explorations of the outer Solar System.

The anticipated need for more fecund sources of space power has led three US government agencies, NASA, the Department of Energy and the Space Defense Initiative Office, to combine their efforts into the SP-100 programme for producing power from nuclear energy. The SP-100 project office is at the Jet Propulsion Laboratory; major support is being provided by the Los Alamos National Laboratory in New Mexico and NASA's Lewis Research Center in Ohio.

The programme began in February 1983 with several objectives:

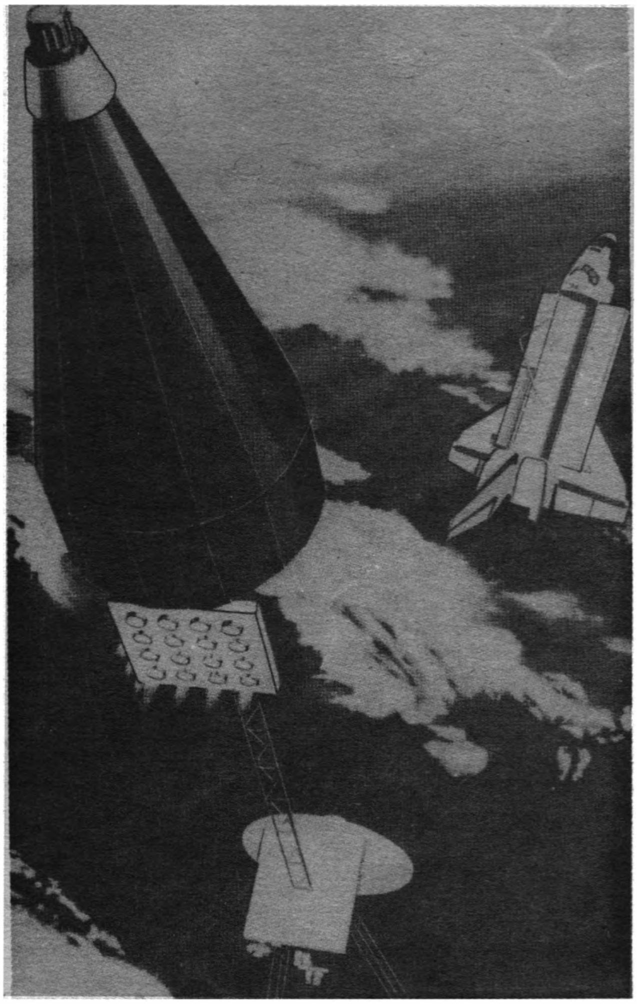
1. to investigate potential space missions in the 100 to 1000 kW range (for comparison, each Voyager spacecraft consumes about 400 watts of electrical power),
2. to develop the technology to build such systems, to be completed in time for missions in the early 1990's,
3. to begin to develop the technology for multi-megawatt nuclear reactors for more long-range space applications.

The first phase, technology definition, will continue until October of this year when the second phase, consisting of ground testing of various components and subsystems, will start up and continue for five years.

What types of missions might benefit from nuclear-electric power? Two deep-space missions, a close-up study of Saturn's rings and a reduced-time flight to Neptune, were described in the April and June 1983 editions of this column. For these cases the nuclear-electric power system would provide the propulsive needs of the spacecraft, by expulsion of ions, as well as energising its electrical systems. Applications in Earth orbit would be a high-powered communications satellite, an air traffic control system (using space-based radar), a space tug to transport material from low Earth orbit to geosynchronous orbit, and materials processing onboard Space Station.

A more advanced mission would employ a 6 MW reactor to service a manned mission to Mars. One mission scenario provides for a 600 day trip to the Red Planet, 30 days spent by the crew on the surface and a 270 day return trip to Earth.

There are three components in a nuclear power system for space: the reactor itself, an energy conversion system and a radiator to dispose of excess heat. Several types of reactors are being considered but all share the feature of operating at higher temperatures than Earth-based reactors because of inefficient power conversion and



After being released from the Shuttle, a conventional interplanetary spacecraft, attached to a nuclear-electric propulsion unit (the conical device), begins its low-thrust escape from Earth orbit. *NASA/JPL*

waste-heat rejection systems. These temperatures will be 1200°C or higher compared to the range of 300-500°C for reactors on Earth. Several conversion systems have been proposed, including the Stirling engine, which was invented in 1816 and performs work by expanding a gas at high temperature. Generally, more than two-thirds of the total thermal output of the reactor is not converted into electrical power and must be radiated into space.

A prime consideration of the SP-100 programme is to develop missions and methods that have a very high degree of safety engineered into them. The reactor will be launched 'cold' and will be turned on only after reaching stable Earth orbit. This orbit must be sufficiently high so that the reactor cannot re-enter under atmospheric drag for at least 300 years, when most of the radioactivity will have decayed.

The SP-100 project at JPL is managed by Dr. Vincent C. Truscello, who has written with co-author Herbert S. Davis a survey paper on nuclear-electric power in space in the December 1984 issue of *IEE Spectrum.*

THE HYPERCUBE

A new and powerful type of computer, the Hypercube, is being developed at Caltech and JPL. This machine belongs to the class of computers called 'concurrent processors.' A concurrent processor is a set of computers that are arranged to work together to solve a single problem. Most present-day computers operate in a sequential mode.

Three basic questions face the designers of a concurrent processor: 1. How many individual computers should be wired together?; 2. What type of wiring scheme should be employed? and 3. What should the nature of the individual computers be?

The answer formulated to the second question by the Caletch/JPL team gives rise to the name 'Hypercube.' Consider the case of eight individual computers. The computers, often referred to as 'nodes' in this geometric context, are wired together such that they can be visualised as lying at the eight vertices of a cube, one per vertex, and the 12 connecting wires lie along the 12 edges of the cube. Thus, each node is directly connected to three others, and only indirectly to the other four nodes in the set. Mathematicians have defined cubes in spaces of dimension greater than three, the so-called hypercubes. In a space of n dimensions there are 2^n vertices in a hypercube and each node in this configuration is connected along the edges of the hypercube to n neighbouring nodes.

The answer to the third question depends upon the objectives of the designer. The Hypercube's designers want to build supercomputers at low cost. Hence, the individual computers should be low-cost devices, and today's microprocessors fit that description. The stated objective of constructing a supercomputer also implies, at least qualitatively, the answer to the first question as to how many nodes should be utilised: lost!

The picture, then, that emerges of the Hypercube is a set of 2^n microprocessors wired together in a definite way and each working on some small aspect of a large problem, exchanging information and results with neighbours as required. What sort of problems are soluble on the Hypercube?

Clearly, a problem must be amenable to decomposition into a set of smaller problems, so that each microprocessor can chew away on one of these subproblems. Dr. Geoffrey Fox of Caltech leads the overall effort, the Caltech Concurrent Computation Project, and has made the Hypercube's capabilities available to a wide variety of investigators at Caltech and JPL. Scientific fields that have been addressed include: quantum mechanics, the large scale structure of the Universe, galactic dynamics, chemical reactions, partial differential equations, image processing (a subject dear to the collective heart of JPL), geophysics and fluid mechanics.

The first version of the Hypercube, Mark I, was built at Caltech and has been running successfully since October 1983. It contains 64 nodes (so that the conceptually associated hypercube would lie in a space of six dimensions) and each node is filled by INTEL 8086/8087 microprocessors: a computer that is similar in performance to an IBM PC. The total performance of the Mark I Hypercube is approximately equal to ten times that of the very popular VAX 11/780 general-purpose computer. See the paper by Fox and Steve Otto in the May 1984 edition of *Physics Today.*

The Mark II version of the Caltech/JPL Hypercube, which is being built at JPL as part of the Laboratory's Advanced Microelectronics Program (AMP), will have up to 128 nodes with each node having twice the memory (a quarter of a megabyte; one byte equals 8 bits of capacity) of the Mark I microprocessors. This Hypercube will have approximately 30 times the performance of a VAX 11/7780, or perhaps 1/3 that of the Cray-1 supercomputer. David Rogstad leads the JPL effort that is building operating-system software for the Hypercube as well as hardware.

A Mark III system is now in the design stage and will

be built around 256 Motorola 68020 microprocessors (in the world of comparisons, this might be equal in performance to the Cray-2 supercomputer). One of the AMP goals is eventually to work with Caltech on the design and implementation of a machine containing 1024 microprocessors, a device that would have a computing capability 50 times that of the Cray-1, today's fastest commercially available sequential computer.

Fox believes that the vast majority of scientific and engineering problems can be effectively handled on the Hypercube but it will require five to ten years to build a software base for concurrent machines that is competitive with the software that exists for sequential machines. The ultimate Hypercube could contain tens of thousands of nodes and exhibit a performance 1000 times that of Cray-1.

ARTIFICIAL INTELLIGENCE

Recently, the JPL Director announced the formation of a Laboratory initiative on the subject of artificial intelligence (AI). This action should help to coordinate present efforts in several areas such as robotics, autonomy and AI *per se*. One component of the activity will be examined here: the application of AI to planning observing sequences for the Voyager mission to Uranus (Voyager 2 encounters the planet on 24 January 1986).

The term 'artificial intelligence' is a misnomer in that it implies more capability (with the word 'intelligence') than present computer programs can deliver. However, it is embedded in current usage and we will resist the temptation to replace it with 'somewhat adaptive software' or other, more modest, labels.

Artificial intelligence, as practised, is not simple to define succinctly, but it generally refers to the effort to construct computer programs that display adaptive behaviour in novel situations and can discern relationships between facts. Also, AI is goal-oriented; the machine is trying to accomplish some task prescribed by its builder and in a way that is not as rigidly set out as is the usual numerical-calculation-by-machine. The eventual goal is to of the word. The popular book *Godel, Escher, Bach: an Eternal Golden Braid* by Douglas R. Hofstadter analyses the world from the perspective of a practitioner of AI.

In the mid 1970's a Mars Rover mission was being studied at JPL. The mission required adaptive behaviour on the part of the Rover, so that some AI techniques were employed. From this work a capability grew that was eventually, in the early 1980's, applied to the Voyager project.

On Voyager, as is the case for other flight projects, it is periodically necessary to transmit by radio to the spacecraft a new set of operating instructions for the onboard computer. Each set of operating instructions, called a 'sequence,' directs the cameras and other instruments and engineering devices to carry out the desired programme of scientific investigation. For Voyager a sequence could operate for as long as six months or as short as one day. When Voyager flies by a planet, it 'uses up' its sequenced instructions rapidly. In the more placid cruise period between planets, a sequence will last longer since there are fewer activities required per unit of time.

Building a sequence is a complex, labour-intensive process, and it was thought that AI could lend a hand (an irresistible anthropomorphism). Specifically, the task was set of arranging the desired observations and other spacecraft activities in a conflict-free timeline. 'Conflict free' refers to satisfying all of the sequence goals without violating any mission constraints, e.g., do not point the spacecraft's camera at the Sun. Such a schedule of activities, whether done by human or machine, forms the basis for building the spacecraft sequence.

Dr. Steven Vere responded with the AI program DEVISER (one 'devises' sequences). Originally DEVISER was run on a PDP-10 computer at the University of Southern California because AI programs require special kinds of programming languages (this one was called INTERLISP). When JPL acquired a Symbolics 3600 computer (with the language ZETALISP), DEVISER was able to come home. A small group of people was formed to adapt DEVISER to the Voyager/Uranus encounter: the Unified Process Control Automatic Technology (UPCAT) group.

The application to the Voyager mission to Uranus consisted of generating timelines with DEVISER for the period near closest approach to the planet and just after this period of time. These timelines were then compared with ones constructed by humans for the same span of time.

The result was that DEVISER produced credible timelines but, generally, the human-generated timelines were more optimal. In addition to the timeline of scheduled events, the program calculated a list of consumable items that the spacecraft sequence used up: hydrazine gas for turns, amount of computer memory, etc.

The learning experience on Voyager pointed out to UPCAT several directions for future program development and practice (during the Voyager/Uranus demonstration, schedules were so tight that few fundamental changes were possible). First, AI programs depend heavily upon knowledge bases: stocks of information concerning their subject matter, in this case the Voyager project. It was felt that more effort needed to be put into developing the knowledge base for DEVISER. Second, several technical changes were identified in the strategy with which the program approached its task. For example, DEVISER always assumed that all parts of the task it had been given were, in fact, possible to do. Like a human it should be taught that not all things are possible.

Application of DEVISER to Voyager served to strengthen the program, in much the same way that we saw the Hypercube effort invigorated by its involvement in physical applications.

The UPCAT group is carrying on its use of AI by working with NASA's Marshall Space Flight Center on the scheduling of observations for Spacelab 3. Also, in view of the promising start made on Voyager, consideration will be given to developing timelines for the Neptune mission.

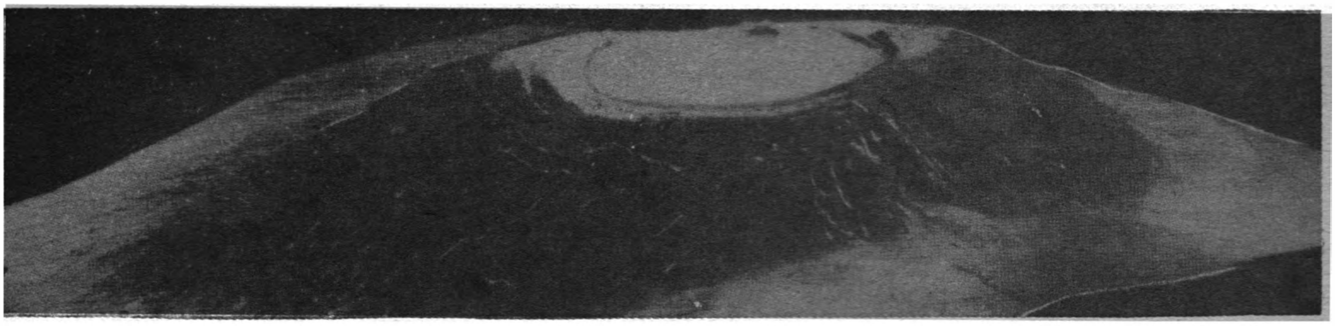
The use of AI is only in its infancy and commercial expenditures in this area are expected to mushroom in the next ten years. Within NASA, the NAVEX effort of the Johnson Space Center is an application of AI to Shuttle navigation that, like DEVISER, is being run in parallel with humans as a test.

Future editions of 'Space at JPL' will look at other developments in AI at the Laboratory.

VIKING TECHNOLOGY

In 1975 two spacecraft were launched from the Kennedy Space Center to begin the Viking mission to Mars. A total of four vehicles were deployed, the two Orbiters and the two Landers, for a programme of exploration that began upon arrival at Mars in the summer of 1976.

The Viking project was the largest and most complex interplanetary effort that has been mounted to date and



A three-dimensional resconstruction of the largest Martian volcano, Olympus Mons. This volcano measures over 600 km across at the base and is about 27 km high. The representation shown here was assembled from Viking Orbiter images. *US Geological Survey*

provides a good chance to observe the interplay of technology with the realities of project life. New technology is not incorporated into a project without reference to needs, cost, schedule and risk.

A detailed history of the Viking project is available in the excellent new publication *On Mars: Exploration of the Red Planet 1958-1978* by E.C. Ezell and L.N. Ezell (NASA SP-4212, a 1984 release in the NASA History Series). This publication, which devotes over 500 pages to Viking and its antecedents, has been used as the basis for most of these present remarks on technology.

The Viking Orbiter and Viking Lander arose from two distinct lines of inheritance. The Orbiter design could trace its genealogy back through the Mariner 9 orbiting mission about Mars (launched in 1971) and the even earlier Mariner missions to Mars and Venus. The Viking Orbiters were built by JPL and, in turn, they have provided inheritance for subsequent Laboratory spacecraft such as Voyager, Galileo and the proposed Mariner Mark II series. For example, the baseline design for the control systems that maintain the Voyager spacecraft in their proper orientations was derived from that for the Viking Orbiters.

The Lander design could not benefit from as direct an inheritance as the Orbiter; certainly the Surveyor lunar-landing missions of the previous decade were relevant but the Surveyor tasks were simpler and the lunar landers were not required to sustain the level of autonomy that the Mars landers needed. The Martin Marietta Corporation was the system contractor for the Landers, while NASA's Langley Research Center was responsible for management of the Viking project.

At a very high level one can observe the interplay between technology and cost by examining Table 46 (p.269) of the Ezell book and noting the continual growth over seven years in the estimated total cost of the Landers while the Orbiters' total estimated cost trended downward (on the recently-completed IRAS project, the technologically-advanced telescope experienced cost growth while the spacecraft, with a more extensive base of inheritance, experienced a more stable fiscal environment). These cost trends were not independent, since Lander increases were sometimes financed by instituting economy measures in other parts of the project, including the Orbiter (this degree of freedom did not exist within IRAS because the telescope and the spacecraft were built in different countries).

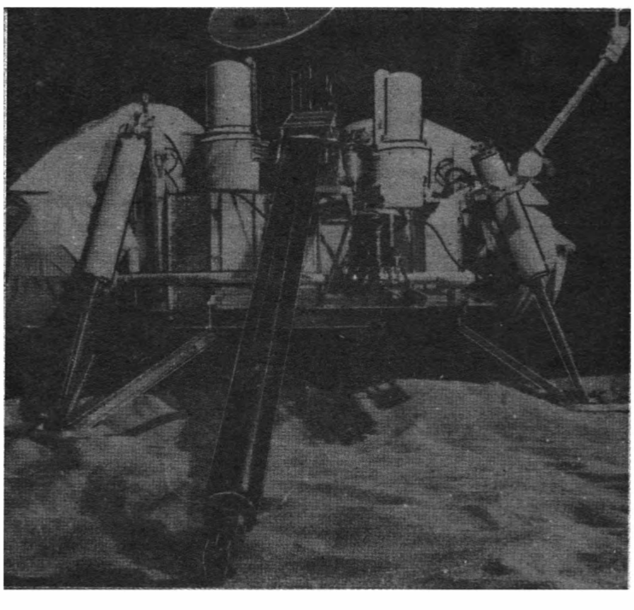
The rationale for incorporating change or new technology into a spacecraft design was spelled out by JPL engineers in the final report on the Mariner 9 mission. This prescription, relevant to Viking Orbiter design, stated that modifications had to meet at least one of three criteria to be employed: 1. adapt the previous design to unique requirements for the new mission; 2. overcome difficulties demonstrated in the previous mission, and 3. incorporate new technology when a major improvement would provide a significant benefit in cost, weight or reliability.

The list of changes incorporated into Viking subsystems is long and only a few can be mentioned. The Orbiter TV subsystem was extensively modified from that flown onboard Mariner 9 in order to achieve better performance, including better resolution and greater flexibility in the choice of filters. Landing site selection played an important and dramatic role in the Viking mission when the original 4 July 1976 landing date on Mars was postponed as a result of the inhospitable terrain imaged by the Orbiter cameras as they revealed much finer (and more disconcerting) detail than did Mariner 9. Viking navigation also benefited considerably from the use of optical navigation, a technology that was proved earlier by the Mariner 9 Optical Navigation Demonstration.

Two of the most important instruments onboard the Landers, the gas chromatograph-mass spectrometer (GCMS) and the Viking biology instrument, represented major technological advances in the instrument design. The first instrument was used to analyse the composition of Martian soil samples; the second consisted of three experiments as part of Viking's search for life on Mars. Both instruments carried a high price tag in dollars and developmental agony but they functioned beautifully on Mars; high technology had been successfully introduced into a spacecraft as a response to mission need. A third example of new Lander technology was the guidance, control and sequencing computer with its advanced plated-wire memory. This device was essential to descent from orbit and to landed operations. After a difficult period of development, it too functioned with great success.

Most technological innovation is associated with the

A model of the Viking Lander in a Mars simulation laboratory at JPL.



prelaunch, design phase of a project. However, digressing for a moment to the Voyager project, there is another route: extensive reprogramming of onboard computers after launch to achieve new capabilities. Voyager has introduced onboard data compression, improved the pointing capability for its instrument platform and even redefined its onboard-computer memories. These opportunities arise from the changing requirements of this long-lived mission as it flies by four planets in the decade 1979-1989: Jupiter, Saturn, Uranus and Neptune (your correspondent co-authored with D.M. Wolff the recent AIAA paper 'Voyager Flight Engineering: Preparing for Uranus' on this topic).

A virtue of the post launch approach to the introduction of new technology is that it achieves economy and effectiveness through the certain identification of need.

Is there a lesson to be learned from the Viking experience? Viking verified the lessons learned from Apollo: high technology can be utilised effectively to satisfy space-programme goals if it is accompanied by realistic costing in time and money (including reserves), experienced personnel and good systems engineering. Also, it helps to have a strong leader and none was ever better than the Viking project manager, Jim Martin of Langley.

IRAS CATALOGUE DELIVERED

The primary purpose of the Infrared Astronomical Satellite (IRAS) project was to produce an all-sky catalogue of infrared sources in the wavelength range of 8 to 120 microns. That purpose has now been accomplished with the delivery on 29 November 1984 of a catalogue of 245,839 point sources: stars, galaxies and other astrophysical objects. The catalogue products were delivered to three data centres: National Space Science Data Center (USA), Rutherford Appleton Laboratory (UK), and Sterrewacht, Huygens Laboratorium (Leiden, the Netherlands).

The catalogue lists the position and positional uncertainty of each point source along with its brightness in up to four infrared wavelength regions as well as other supporting information. The catalogue itself is contained on two magnetic tapes and the explanatory supplement accompanying it fills some 400 printed pages. Additional computer tapes contain some of the more primitive data from which the catalogue was constructed (the 'working survey data base') and visual maps of certain portions of the survey have been fashioned.

IRAS project manager Gael Squibb of JPL says that it may well be the highest quality large catalogue in existence: the reliability level is better than 1 part in 100,000. This means that there may be no intruders (asteroids masquerading as astrophysical sources, noise artifacts, etc.) in the catalogue of more than 200,000 sources. It was also delivered more quickly after the end of the mission (November 1983) than any similar data product from a space mission. Squibb ascribed the high quality and rapid production to the dedication and skill of the staff that produced it. He said that they were self-motivated and insisted upon the highest standards, working through holidays where necessary to meet production schedules without compromise of quality.

IRAS itself is now being phased out but the data returned by the satellite have not been exhausted. All three countries that were involved in the joint IRAS project are making independent plans to facilitate the use of this data within the scientific community. NASA is planning to fund the Infrared Processing and Analysis Center (IPAC) at JPL through fiscal year 1989.

The IPAC effort will be concentrated in two basic areas: (1) reprocessing the IRAS data to achieve greater sensitivity, thus extracting more point sources and (2) serving as a research centre for astronomers who wish to examine the IRAS data in depth for special-purpose investigations.

A WEEKEND IN BRIGHTON

It was a pleasure to return to Brighton for the Society's Space '84 weekend, held 16-18 November 1984.

Richard Laeser, the Voyager project manager, and I arrived at Heathrow in midafternoon and, after a parity reversal to adjust for the left hand side of the road, drove down to Brighton for the initial ceremonies. This biannual event was held again at the Brighton Centre, a modern convention facility.

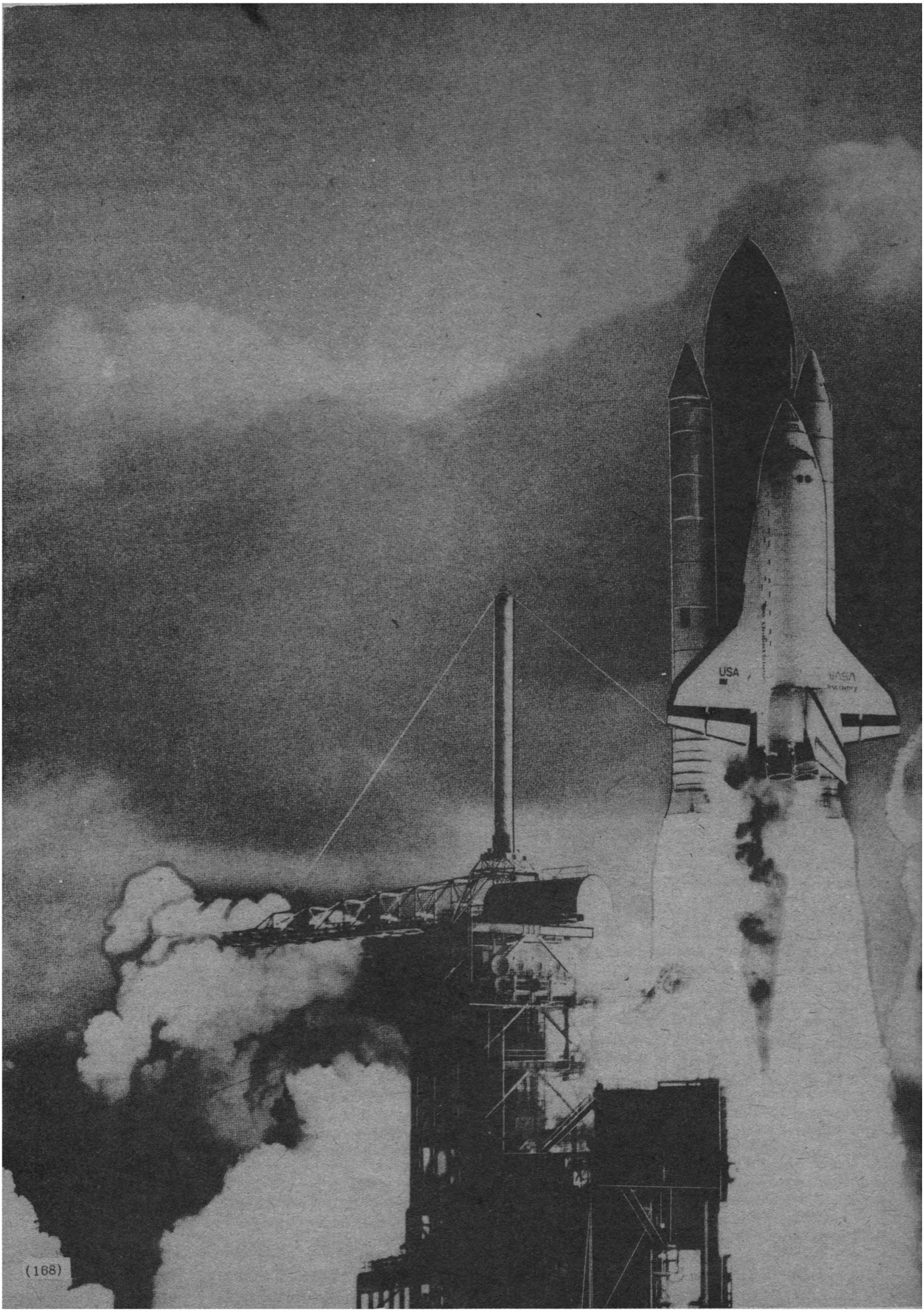
Presentation of papers began on Saturday morning. I was the first of the four JPLers to speak, on the topic of 'The Philosophy of Extraterrestrial Intelligence.' Sunday morning, the Project Galileo manager, John Casani, reviewed his mission plan for the exploration of the Jovian system starting in 1988. Then, Laeser spoke on the Voyager mission to Uranus (1986) and Neptune (1989). In an afternoon talk, Rob Staehle treated the subject of autonomy as it relates to NASA's Space Station.

In addition to the formal aspects of the meeting it was enjoyable to renew old acquaintances and create new ones. Len Carter was socially obscured, understandably, by the organisational web that he and Martin Fry wove to keep Space '84 functioning smoothly, but we did manage to snatch a few idle moments for conversation. Dr. Anthony Michaelis, a BIS Fellow and editor of *Interdisciplinary Science Reviews,* was present and always a delight to converse with owing to his diverse interests. Group Captain Tim Grant and I touched on the subject of progress in artificial intelligence, reminding me to present some recent JPL work on the subject in the near future in these pages.

At last I got to meet Patrick Moore, author, lecturer *par excellence* and long-time BIS Fellow. In addition to teaching astronomy, he has done selenographic work, having specialised in the mapping of lunar libration regions (those areas that are only occasionally visible from Earth, as the Moon appears to nod or librate, revealing approximately 59% of its surface to an Earth-based observer over a sufficiently long period of time).

The banquet on Saturday night was held in the meeting room, which had been transformed into a dining room. The table at which I sat started out polarised along Anglo-American lines with four Americans at one end and four Britons at the other end. But we soon mixed it up with vigour, starting when Max Wholey (the Society's Archivist-to-be) passed around a mesolithic hand knife he had found and explained the finer points of its construction and function.

After three days in Brighton I went to Oxford where even there the long arm of the BIS partially guided my activity. The Society is researching into the history of its copy of the *Uranometria* star atlas in order to determine who compiled it. I contributed a small amount by going through some of the correspondence of the astronomer James Bradley, the discoverer of the aberration of starlight. Although I did not discover anything relevant, it was exciting to go through the Bodleian Library's collection of these old letters and read subjects ranging from bad travel conditions between Oxford and Greenwich to the motions of the satellites of Jupiter. How it would have startled and pleased Bradley had he known of the exploration of the Jovian system by the Voyager and Galileo spacecraft!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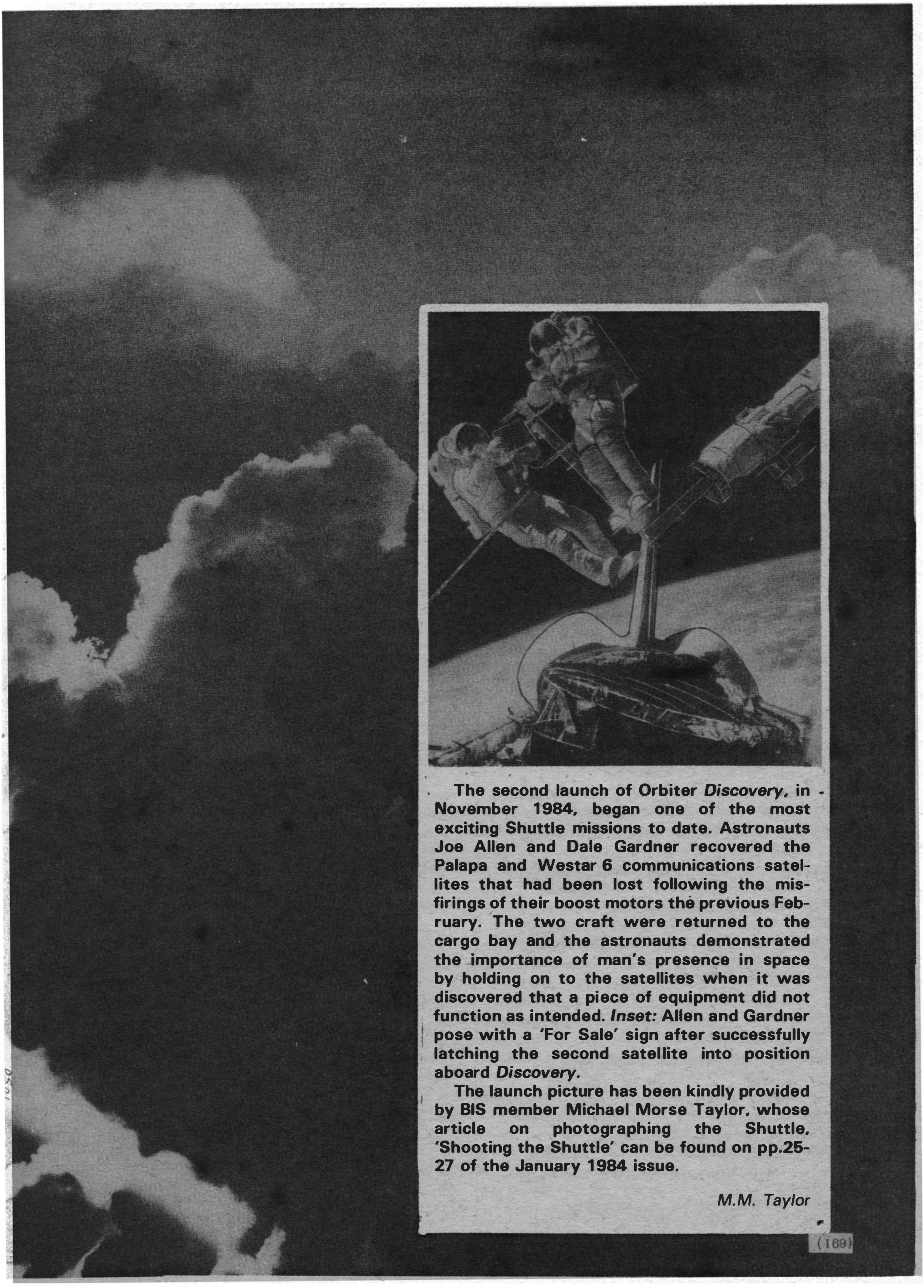

The second launch of Orbiter *Discovery*, in November 1984, began one of the most exciting Shuttle missions to date. Astronauts Joe Allen and Dale Gardner recovered the Palapa and Westar 6 communications satellites that had been lost following the misfirings of their boost motors the previous February. The two craft were returned to the cargo bay and the astronauts demonstrated the importance of man's presence in space by holding on to the satellites when it was discovered that a piece of equipment did not function as intended. *Inset:* Allen and Gardner pose with a 'For Sale' sign after successfully latching the second satellite into position aboard *Discovery*.

The launch picture has been kindly provided by BIS member Michael Morse Taylor, whose article on photographing the Shuttle, 'Shooting the Shuttle' can be found on pp.25-27 of the January 1984 issue.

M.M. Taylor

MEET THE UK ASTRONAUTS

The first Briton to travel into space is due to go aloft in 1986 aboard the Space Shuttle with a UK Skynet communications satellite. All four of the candidates in training - Nigel Wood, Richard Farrimond, Peter Longhurst and Chris Holmes - will be Guests of Honour at a special dinner to be held at Society headquarters on the evening of Friday, 21 June 1985.

This is a unique opportunity to meet the men who will be part of space history. There are only a limited number of places available, so early application is essential. The cost (including sherry, 4-course meal and a half bottle of wine) is £18 per person.

Registration forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Top left: Nigel Wood (RAF), *top right:* Richard Farrimond (Army); *bottom left:* Peter Longhurst (RN); *bottom right:* Chris Holmes (MoD).

JBIS

The April issue of the Journal is devoted to Astronautics History' under the editorship of space historian Mitchell Sharpe. The following papers are included:

1. 'The Rocket as Spacecraft: Spent Stages in Manned Space Flight,' by W.D. Compton;
2. 'Pioneering Commercial Rocketry in the United States,' by F.H. Winter and F.I. Ordway;
3. 'A Study of Early Korean Rockets (1377-1600),' by Y.S. Chae;
4. 'A History of Inertial Guidance,' by F.K. Mueller.

Copies of the issue are available at a cost of £2 ($4) each, post free, from The British Interplanetary Society, 27/29 South Lambeth Rd., London SW8 1SZ, England. Copies of the December 1983 issue of 'Astronautics History' are available at the same price.

The March issue of the Journal is devoted to 'Interstellar Studies.' The papers include:

- 'Suspended Animation for Space Flight,' by J. Hands.
- 'Can Population Grow Forever?' by P. Birch.
- 'Trend Analysis for Interstellar Ramjet Technologies,' by R.J. Stalker.
- 'On the Potential Performance of Non-Nuclear Interstellar Arks,' by G.L. Matloff.
- 'Non-Nuclear Interstellar Flight,' by G.L. Matloff and E. Mallove.
- 'Plasma Expansion in the Daedalus First Stage Engine,' by J.O. Elliott and W.K. Terry.

DELUXE CERTIFICATES

Both Fellows and Members may now purchase high-quality certificates suitable for framing. These are 29.5 x 41.5 cm in size, printed in three colours and with the member's name hand-inscribed. They are available for only £5 ($8) post free.

When ordering, please indicate membership grade and allow six weeks for delivery. Provision for ordering these certificates also appears on the 1985 subscription renewal form.

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

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THE INTERNATIONAL HALLEY WATCH

By Stephen J. Edberg

Halley's comet has been on the minds of many people for some years now. In the course of NASA studies of the possibility of spacecraft exploration of the comet at its next appearance, Louis Friedman, then of the Jet Propulsion Laboratory, convinced NASA that a study of international research collaboration would be valuable. A year's study produced a report [1] recommending the inauguration of an International Halley Watch (IHW). The author, of the Jet Propulsion Laboratory in California and IHW Coordinator for Amateur Observations in the western hemisphere, describes the project.

Introduction

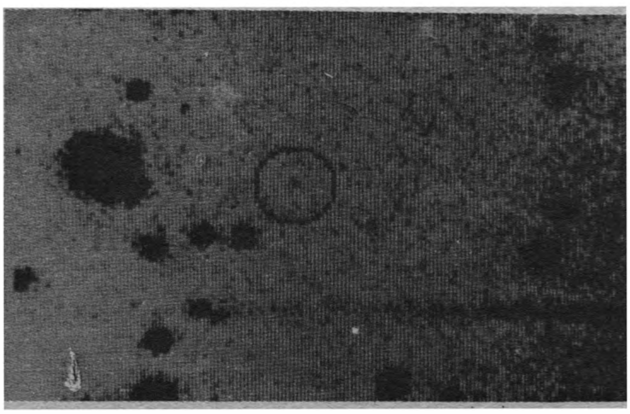
The IHW is organised around two Lead Centers, one at the Jet Propulsion Laboratory in Pasadena, California and the other at Bamberg in West Germany. The two centres serve as communications links between astronomers and observatories in the two hemispheres, the eight discipline specialist (DS) teams organising observers around the world, the space flight projects investigating the comet, amateur astronomers, the media and public. Their most important work is to organise and publish the Halley Watch Archive, planned as the most complete collection of data ever assembled on a comet. The staffs of the two centres (Table 1) are small and most are engaged in other activities.

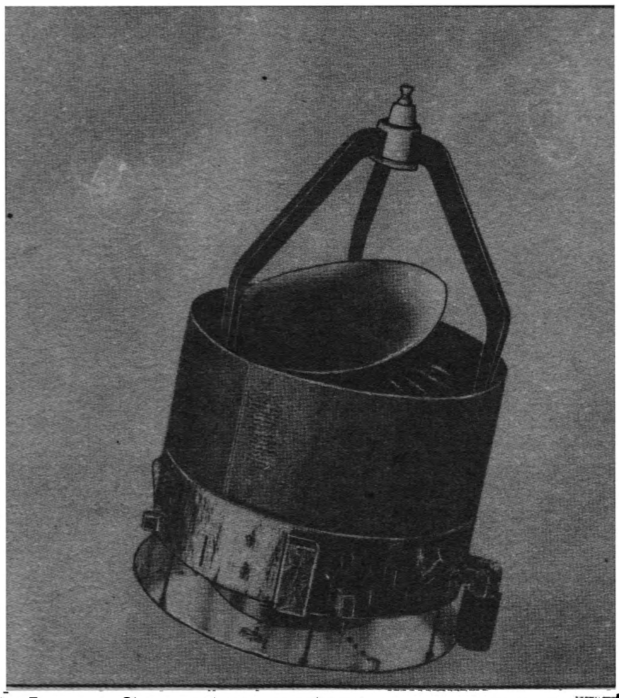
The archive will be compiled on computer tapes submitted by the discipline specialists, who will collect observations from astronomers worldwide. While the detailed organisation of the archive is still under consideration, it is expected to be laid out on a daily basis, recording all observations made that day by each discipline, including some contributions by amateur astronomers. Only meteor studies and the overall light curve of the comet will be treated differently since the Halley-related meteor showers are limited to certain times of the year and the light curve is intended as an overall description of this apparition of Comet Halley.

After the Lead Centers were organised, a Steering Group of distinguished cometary scientists (Table 2) from many nations was initially appointed by NASA. Their rôle is one of advising and overseeing the activities of the Lead Centers and the discipline specialists. The group now has its own chairman and appoints its own members.

The Discipline Specialist Teams (Table 3) are made up of experts in the field. They serve as information resources, observation coordinators and data compilers, receiving the observations made by cooperating astronomers around the world. Each DS team is international, its initial members having been selected by the steering group. Other members were then invited by the selectees.

Discovery image of Halley's comet for the present apparition. It was found on 16 October 1982 using a charge-coupled device camera on the 5 m Hale Telescope at Mount Palomar in California. *Caltech*





The European Giotto probe approaches the comet. *BAe*

The Discipline Specialist Teams

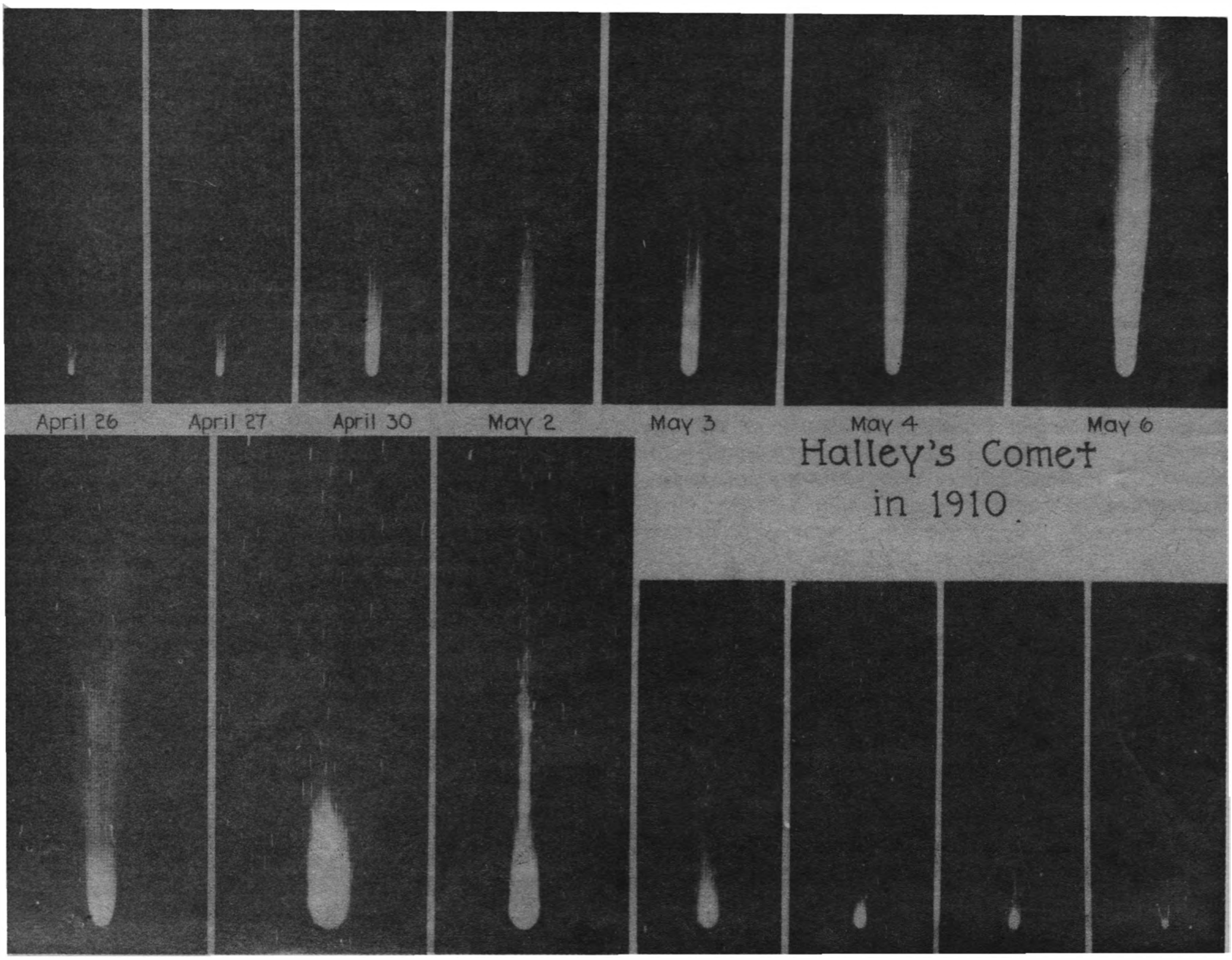
There are eight DS teams, each representing a different area of astronomical technology or investigation. While they operate independently, it is in everyone's best interest to coordinate their observations as much as possible with other disciplines and with the space flight projects. This has been accomplished in part by setting up Halley Watch Days on which everyone will attempt

Table 1. IHW Lead Center Staffs.

Eastern Hemisphere Office	Western Hemisphere Office
Leader: J. Rahe	Leader: R.L. Newburn, Jr.
Deputy: H. Dreschel	Deputy: M. Geller
Ass't for Amateur Activities: R. Knigge	Coord. for Amateur Observations: S.J. Edberg
	Archive Editor: Z. Sekanina

Table 2. IHW Steering Group Members

W.I. Axford, New Zealand	R. Lust, FRG
M.J.S. Belton, USA	A. Massevitch, USSR
J. Blamont, France	A.J. Meadows, UK
G. Briggs, USA	C.R. O'Dell, USA
A. Delsemme, USA	R. Reinhard, The Netherlands
B. Donn, USA	H.E. Schuster, Chile
H. Fechtig, FRG	K.R. Sivaraman, India
L. Friedman, USA	V. Vanysek, Czechoslovakia
S.M. Gong, China	J.F. Veverka, USA
I. Halliday, Canada	K.W. Weiler, USA
G. Herbig, USA	G. Wetherill, USA
L. Kresak, Czechoslovakia	F.L. Whipple, USA
Y. Kozai, Japan	Ya.S. Yatskiv, USSR



observations so that data from the various disciplines can be directly correlated.

The Astrometry Network has the important job of not only receiving but analysing accurate position measurements of Comet Halley. These will be used to generate the ephemeris updates necessary for the probes navigating to encounters with the comet and for telling other astronomers where to point their instruments. Detailed investigation of Halley's orbit can be used to infer details of processes occurring in the comet's nucleus. In particular, the so-called non-gravitational forces affecting the comet's motion place constraints upon the quantity of ejecta and the rotation rate and axial orientation of the nucleus.

Table 3. Discipline Specialist Teams

Astrometry
D.K. Yeomans, JPL
R.M. West, ESO
R.S. Harrington, USNO
B.G. Marsden, CFA

IR Spectroscopy & Radiometry
R.F. Knacke, SUNY (Stony Brook)
T. Encrenaz, OBS., Meudon

Large-Scale Phenomena
J.C. Brandt, GSFC
M.B. Niedner, GSFC
J. Rahe, OBS., Bamberg

Near-Nucleus Studies
S. Larson, Univ. of Arizona
Z. Sekanina, JPL
J. Rahe, OBS., Bamberg

Photometry & Polarimetry
M. A'Hearn, Univ. of Maryland
V. Vanysek, Charles Univ.

Radio Studies
W.M. Irvine, Univ. of Mass.
E. Gerard, OBS., Meudon
R.D. Brown, Monash Univ.
P. Godfrey, Monash Univ.
F.P. Schloerb, Univ. of Mass.

Spectroscopy & Spectrophotometry
S. Wyckoff, Ariz. St. Univ.
P.A. Wehinger, Ariz. St. Univ.
M.C. Festou, Inst. d'Astrophys

Meteor Studies
(The DS Team is presently being selected.)

The Infrared Spectroscopy and Radiometry network concerns itself with the wavelength region ranging from about one micrometre (=10^{-6}m) to one millimetre. The data here are especially useful in studies of the composition and size distribution of dust particles released as the nucleus sublimates. In addition, studies of the overall energy balance will be possible and molecule searches and identifications are likely. This is one network that will be able to operate during solar conjunction around Halley's perihelion (closest approach to the Sun) in February 1986.

The Large-Scale Phenomena Network is concerned with the comet's tails. Using wide field (~5°) cameras, primarily of the Schmidt type, this network plans to study both the ion and dust tails of the comet. Since changes in the ion tail can occur on time scales of minutes, this network's observers are spread in every possible longitude zone to provide continuous, 24 hour coverage of the comet (as weather permits). Portable telescopes are being moved to a number of southern hemisphere islands to reduce gaps in the coverage; one will even be operated by the British Antarctic Survey at Halley Bay in Antarctica. The goal is to understand the interaction of the ion tail and the solar wind, including the puzzling tail disconnection events. The dust tail will not be neglected, with its normally long-term changes monitored with the goal of understanding dust production and disintegration processes and discovering clues on the composition and structure of dust particles. Observations with the Solar Maximum Mission satellite's coronograph should allow observations during solar conjunction.

The Meteor Studies Network is newly organised. Dust

particles released by Halley hundreds of revolutions ago might now collide with the Earth during the two annual Halley meteor showers, the η Aquarids in May and the Orionids in October. Using visual, photographic and radar techniques, this network's study of the meteors should shed light on the dust component of the comet and the physical processes acting on it to bring it into Earth's vicinity.

The Near-Nucleus Studies Network will be making use of the latest in electronic and photographic imaging technology to record the coma - the atmosphere surrounding the solid nucleus. The images will be used to characterise the processes going on in the coma and nucleus, the geography of the nucleus (e.g., the sources of 'fountains' and 'jets' in the coma), and to infer the rotation rate and axis direction of the nucleus.

The Photometry and Polarimetry Network is responsible for measurements of the distribution of coma dust and gases emitting in the 0.3-1 micrometre band. Using specially selected narrowband filters, this network will study the composition of the comet. In particular, measurements of the quantities of 'daughter' molecules will be used to infer the quantities and types of 'parent' molecules. The ratio of gas-to-dust will also be studied. The dimming of stars during an occultation by the comet will be used for studies of the dust quantity and distribution in the head. Polarimetric observations might provide important data on dust particle size, shape and refractive index to help in identifying the chemical compounds forming the particles.

The Radio Studies Network is coordinating various efforts over the whole radio frequency spectrum. Searches for and identification of molecules are planned. There will be studies of molecular production rates and plasma studies in continuum frequencies may shed light on tail processes. Radar studies will be attempted during the close approaches to Earth in November 1985 (0.62 AU) and in April 1986 (0.42 AU). This network will be active during solar conjunction, when the comet will be brightest at radio wavelengths.

The Spectroscopy and Spectrophotometry Network will undertake high resolution visible and near-visible light studies of the spectrum. The identification of molecular species, their quantities, temperatures, and lifetimes are among the goals. Isotope abundance studies might provide clues on the origin of the comet and perhaps on the Solar System.

The start-up dates for the networks vary. The Astrometry and Photometry networks began receiving data with Halley's first sighting on 16 October 1982. Near-Nucleus Studies was minimally active in this period, waiting for the development of a coma (first reported in late September 1984); the first spectra were obtained in October 1983. Infrared observations are expected to begin in the current observing season. The Radio Studies network begins activities in August 1985 and Large-Scale Phenomena will start to monitor tail development a month later. Meteor Studies will probably make use of observations made in past years, continuing to the present and future.

Project representatives (Table 4) have the important duty of informing the Halley Watch of the ground-based observational support needed by the experimenters on the flight projects. Six spacecraft are making approaches to Comet Halley for which coordinated, intensive ground support will be useful: the European Space Agency's Giotto, the Soviet Union's Vega 1 and 2, Japan's Planet-A and MS-T5, and NASA's International Cometary Explorer all make near or distant flybys. In addition, the Space Shuttle is scheduled to carry the Astro-1 payload of ultraviolet and visible radiation instruments for detailed

Table 4. Space Project Representatives

Giotto	ESA	R. Reinhard
Planet-A, MS-T5	ISAS	K. Hirao
Vega 1, 2	Intercosmos	R. Sagdeev
Astro-1	NASA	P. Feldman

Earth orbital studies of the comet during the closest encounters by some of the spacecraft. From its vantage point, the Pioneer Venus Orbiter will be oriented to observe Halley during perihelion. As mentioned earlier, the Solar Maximum Mission satellite in Earth orbit will also be actively observing near perihelion. In the spirit of international cooperation, the space agencies of the flyby spacecraft (ESA, Intercosmos and ISAS) have agreed to add the spacecraft data to the IHW Archives in Pasadena and Bamberg, and the archives are to be reproduced and established at one location determined by each agency.

The Amateur Contribution

Amateur astronomers are also included. With the modern equipment now available to them and the freedom to observe without observatory time allotment committee restraints, amateurs can supply useful primary and secondary data visually, photographically and photoelectrically. Visual observations will be used to generate a brightness versus time curve for Halley, useful in historical and theoretical studies, and in comparing drawings from 1985-86 with near-nucleus images and historic drawings. Photographic efforts can support the Near Nucleus Studies, Large-Scale Phenomena and Astrometry networks, especially in situations where a professional observatory is 'clouded out' and an amateur elsewhere is not. Low dispersion spectroscopy may also prove to be useful to the professional spectroscopy network. Photoelectric observations by amateurs might prove especially useful when Halley is closest and largest in the sky: at that time the smaller images from amateur instruments will make measurements of the whole coma easier. Finally, meteor observations by amateurs will greatly augment the work of the few professional meteor astronomers in the world.

At present, 875 professional astronomers from 47 countries plan to participate with the IHW. Over 200 amateurs from 29 countries have indicated their serious intention to contribute, and this number will grow. The International Halley Watch has world cooperation in its efforts to record for posterity the passage of Halley's comet the second time in this century.

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

REFERENCES

1. The International Halley Watch, Report of the Science Working Group, JPL Publication 400-88, (NASA TM 82181), July 1980.
2. See the report by R. Reinhard in The International Halley Watch Newsletter, Issue No. 5, S.J. Edberg, Ed., JPL, Pasadena, 1 September 1984.

SHUTTLE MISSION 41G

By John A. Pfannerstill

Surveying the Earth from space was one of the major objectives of the 13th flight of the Shuttle. In fact, the record crew of seven astronauts planned to conduct the most extensive programme of observations undertaken on any US manned flight since the Skylab missions of 1973-4.

Introduction

On the agenda for the busy eight-day flight were visual observations of the world's oceans by the first professional oceanographer to go into space, the deployment of a climate research satellite, observations using a large synthetic aperture radar array, and photography of the Earth's surface by a sophisticated aerial camera system.

Also planned was an exciting extravehicular activity (EVA) during which two astronauts would demonstrate techniques to be used on future missions for re-fuelling satellites in orbit. Orbiter *Challenger* was earmarked for the mission; 41G would thus be the craft's sixth trip into space.

The seven-person crew was the largest ever to take off aboard a single spacecraft. They included: Navy Captain Robert L. Crippen (Commander), Navy Commander Jon A. McBride (Pilot), Navy Lieutenant Commander David C. Leestma (Mission Specialist-1), Dr. Sally K. Ride (MS-2), Dr. Kathryn D. Sullivan (MS-3), Canadian Navy Commander Marc Garneau (Payload Specialist) and Dr. Paul D. Scully-Power (PS).

The inclusion of Ride and Sullivan marked the first time that two women had ever flown together in space. In addition, since Ride was a veteran of the STS-7 mission of June 1983, she became the first American woman to make two flights. Sullivan, on the other hand, was scheduled to have the distinction of being the first American woman to make a space walk. Except for Ride and Crippen, the entire crew was going into space for the first time. Garneau and Scully-Power were late additions to the team. As Payload Specialists, they were not NASA astronauts and were allowed on the mission only when NASA decided to fly 41G using the more spacious *Challenger* rather than the originally-scheduled *Columbia*.

Garneau was aboard as part of a joint US/Canadian program of scientific cooperation. As a representative of the Canadian National Research Council, he was the first of three Canadian astronauts scheduled to fly on Shuttle missions. On 41G he was to perform ten scientific experiments developed by Canadian researchers.

Scully-Power was a civilian oceanographer employed by the US Navy. As a recognised expert on ocean studies from space, the Australian-born scientist flew on 41G to conduct research into the data-gathering value of visual observations in oceanography. Astronauts and cosmonauts have commented for years on how much more detail they could see with their own eyes as compared to what a photograph would show of the same scene. Scully-Power intended to discover just how much better a trained eye actually was as an oceanographic data-gathering tool.

Payloads and Experiments

On Mission 41G, *Challenger* carried a payload weighing approximately 8,203 kg, one of the lightest Shuttle payloads ever flown. Nevertheless, the lightweight components took up nearly all of the volume of the payload bay, making it impossible to fill the Orbiter to its full weight-carrying capacity.

Kathy Sullivan making binocular observations from *Challenger's* flight deck windows. NASA

Starting at the forward end of the payload bay and working aft, the 41G payloads included:

1. NASA's Office of Space and Terrestrial Applications (OSTA-3) Payload

Similar to the OAST-1 payload flown on STS-2 in November 1981, OSTA-3 consisted of improved versions of many of the same Earth-viewing instruments. Like OSTA-1, they were mounted on a modified Spacelab pallet. OSTA-3's individual components included:

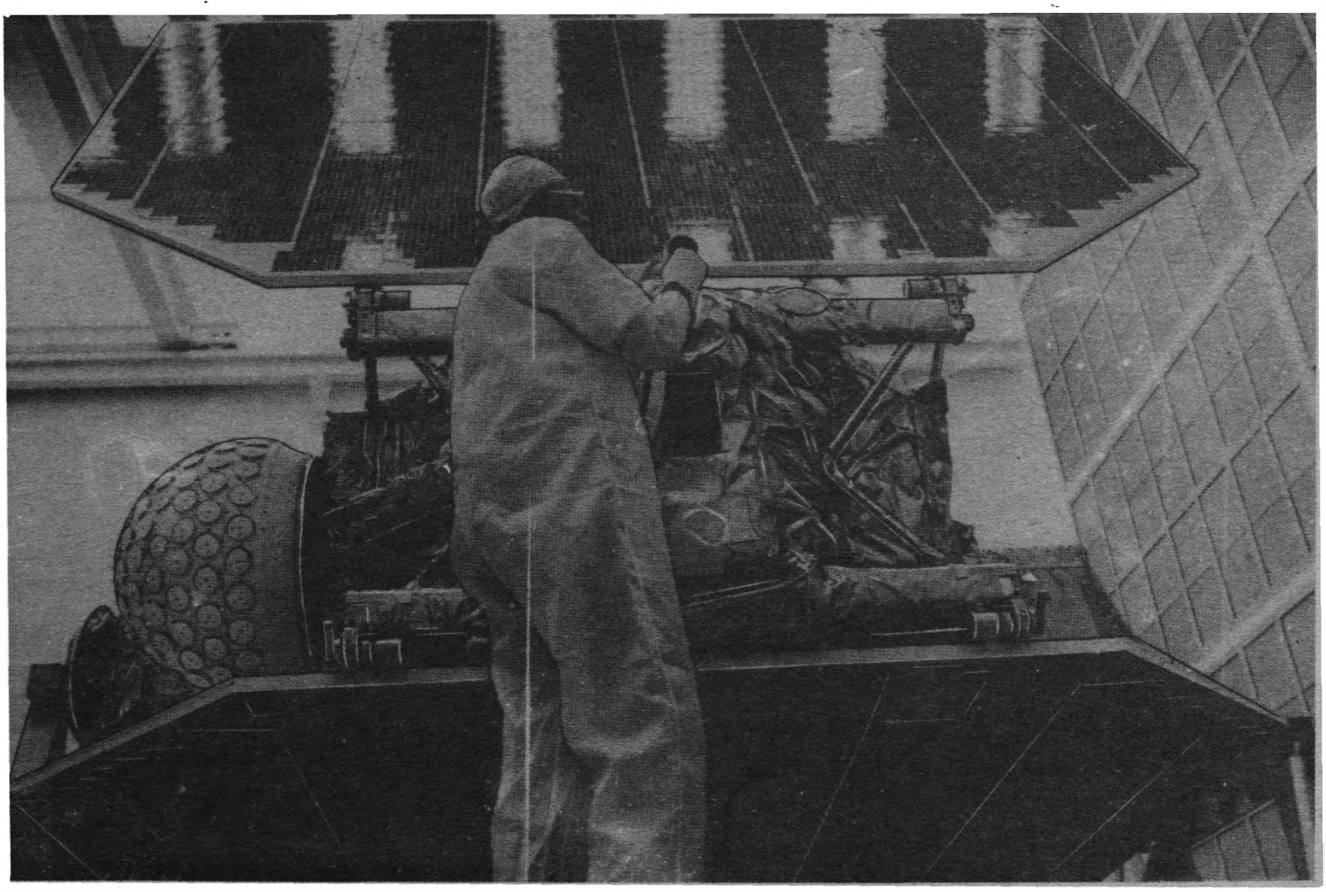
A. Shuttle Imaging Radar (SIR-B): Designed to obtain high resolution radar images of the Earth, SIR-B was expected to show objects as small as 25 m using a 10.7 x 2.1 m planar antenna. This was much larger than the SIR-A antenna of OSTA-1, making it necessary for a folding mechanism to be built into the new array. Hinged in two places, the antenna was folded up during launch, entry and large on-orbit burns, but was to be left open for most of the rest of the mission. The antenna was also equipped with a device that allowed it to tilt, allowing it to view the Earth from a range of angles. Producing data at a rate of 46 megabits per second, it was planned to transmit the data to the ground through the Tracking and Data Relay Satellite (TDRS), which was the only feasible way to handle such a high rate. When gathering radar data out of range of TDRS, the crew planned to record the information on tape for later 'dumping' through the satellite.

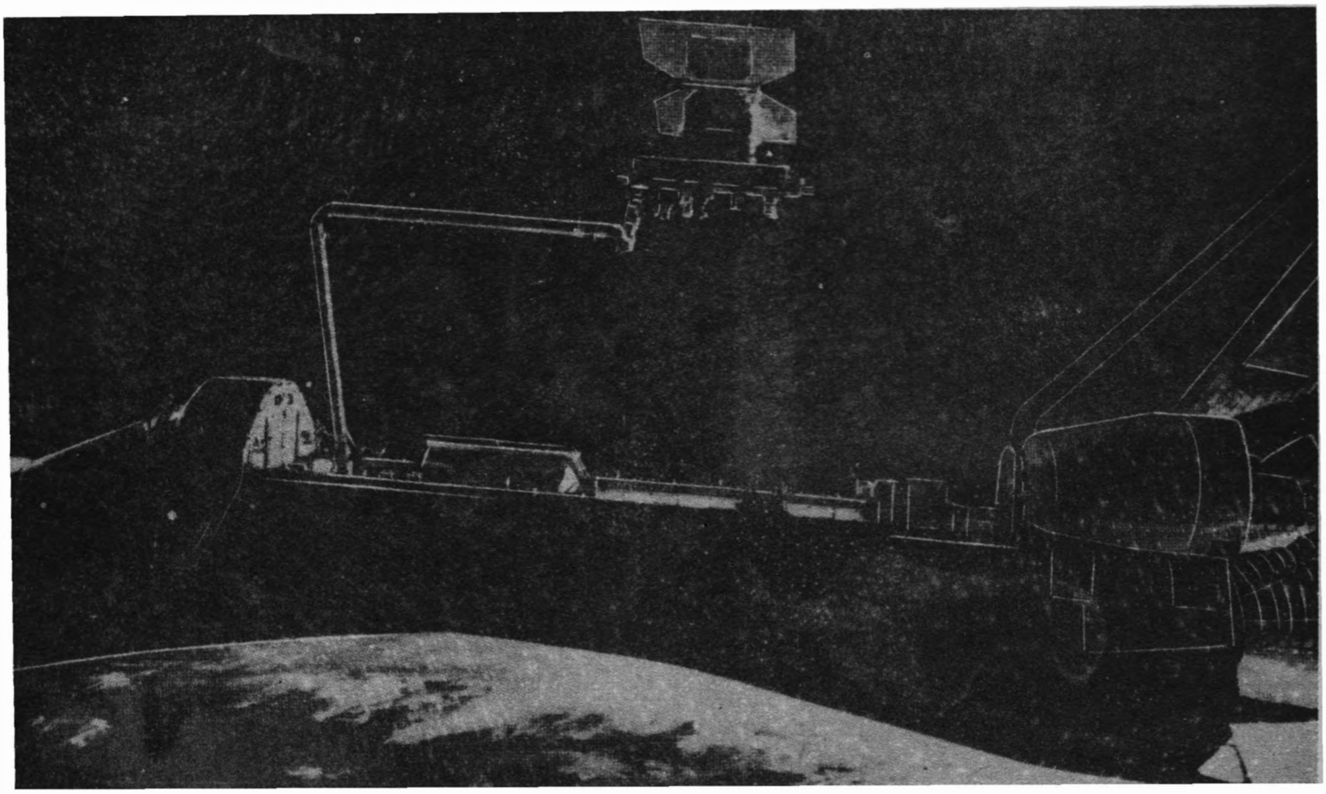
B. Measurement of Air Pollution from Satellites (MAPS): Consisting of an electro-optical sensor, a digital tape recorder and an aerial camera, MAPS was designed to provide information on the distribution of carbon monoxide in the atmosphere. It was essentially unchanged from its configuration on OSTA-1. NASA plans to fly MAPS periodically again in order to monitor the Earth's changing pollution.

C. Feature Identification and Location Experiment (FILE): FILE was designed to aid in the development of a self-limiting data acquisition system for unmanned Earth resources satellites. Using visual red and near-infrared wavelengths, experimenters hope to construct a system that would in effect tell the spacecraft to stop gathering

The 41G crew pose for an in-flight portrait. From left, they are: Jon McBride, Paul Scully-Power, Sally Ride, Bob Crippen, Kathy Sullivan, Marc Garneau and Dave Leestma. *NASA*

The Earth Radiation Budget Satellite





An artist's impression of ERBS being released into orbit. *NASA*

41G's two Payload Specialists hard at work in the mid-deck, Marc Garneau (at left) and Paul Scully-Power. *NASA*

data when (for example) the target to be imaged is covered by clouds. One of the main concerns was making the system sensitive enough to differentiate between snow and cloud cover. FILE data were gathered by two television and two 70 mm film cameras.

D. Large Format Camera (LFC): The LFC was the only part of OSTA-3 not mounted on the Spacelab pallet - it was located at the far aft end of the payload bay on a support truss. This remarkable camera was capable of providing both high resolution (about 21 m from 298 km altitude) and wide field of view (each 23 x 46 cm frame shot from an altitude of 298 km would cover an area measuring 222 x 444 km on the ground). For 41G, the LFC was loaded with five different types of film, spliced together onto a 1,219 m long roll. This was enough for about 2,400 frames.

2. NASA's Earth Radiation Budget Satellite (ERBS).

The only deployable satellite carried on 41G, ERBS is a scientific satellite operated by NASA's Goddard Space Flight Center. The spacecraft is part of a three-satellite mission (involving the NOAA F and G satellites) that has the aim of monitoring Earth's 'radiation budget.' Together, the three satellites will be used to provide a global view of the amount of solar radiation the planet receives *versus* the amount that it radiates back into space. Measurements of this type are extremely valuable to climatologists who wish to understand better regional and global climatic trends. Looking something like an old-fashioned pot-bellied stove with wings, ERBS weighed 2,307 kg at launch. It was planned for deployment on the first day of the mission by the Shuttle's Remote Manipulator System arm.

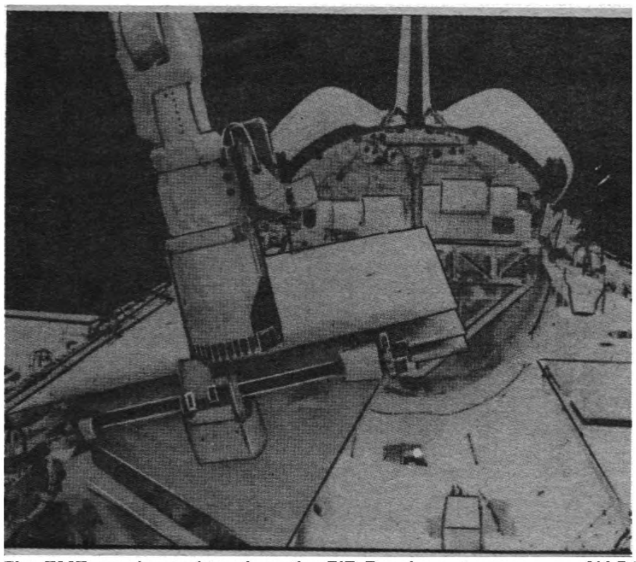
3. Orbital Refuelling System (ORS).

Sharing the same Mission Peculiar Experiment Support Structure (MPESS) truss with the LFC, the ORS was intended to develop techniques for refuelling existing unmanned satellites in orbit. On an early Vandenberg-launched Shuttle polar orbit mission, NASA plans to re-fuel its Landsat 4 Earth resources satellite, which has been in orbit since July 1982. Since Landsat was never designed to be re-fuelled in space, techniques had to be developed that would allow an EVA astronaut to tap into the ground fill panel on the satellite in order to replenish its hydrazine propellant supply. The ORS was designed to provide a fairly realistic simulation of the Landsat operation. The ORS consisted of a 'supply' tank filled with about 85 kg of hydrazine and an empty 'take-up' tank. The take-up tank was connected to a simulated Landsat fill panel identical to that on the actual satellite. During their EVA on Mission Day 5, astronauts Leestma and Sullivan planned to install a special access valve in the panel, permitting them to make the proper plumbing connections from the supply tank to the take-up tank. Once back inside the Orbiter's cabin, they would transfer the hydrazine to the take-up tank by remote control. In addition to the connections to be installed during the EVA, the two ORS tanks were also linked by another plumbing system that would also be used for several fuel transfers. These were scheduled to be done before the spacewalk, checking the dynamics of such an operation in zero-g.

4. Getaway Special (GAS) Payloads.

Scattered throughout the payload bay were a total of eight GAS canisters. This brought to 29 the total number of such payloads flown on the Shuttle to date. The new payloads were:

A. GAS G-0007. 'Space Processing and Transmitting Computer Voice on Amateur Radio Bands,' which was sponsored by the Alabama Space and Rocket Center in Huntsville, Alabama.



The RMS arm is used to close the SIR-B radar antenna. *NASA*

B. GAS G-0013. 'Halogen Lamp Experiment (HALEX),' which had as its sponsor Kayser-Threde in Munich, West Germany.

C. GAS-G0032. 'Physics of Solids and Liquids in Zero Gravity,' sponsored by the Asahi National Broadcasting Company in Tokyo, Japan.

D. GAS G0038. 'Vacuum Deposition (Space Art),' sponsored by sculptor Joseph McShane of Prescott, Arizona.

E. GAS-G0074. 'Zero-g Fuel System Test,' which had as its sponsor the McDonnell Douglas Astronautics Company of St. Louis, Missouri.

F. GAS-G0306. 'Trapped Ions in Space (TRIS) Experiment,' was sponsored by the Naval Research Laboratory in Washington D.C.

G. GAS-60469. 'Cosmic Ray Upset Experiment (CRUX-III),' jointly sponsored by NASA's Goddard Space Flight Center and IBM's Federal Systems Division in Manassas, Virginia.

H. GAS-G0518. 'Physics and Material Processing,' sponsored by Utah State University.

In addition, 41G also flew a number of experiments and equipment inside *Challenger's* pressurised cabin:

1. Canadian Experiments (Canex): This consisted of ten experiments falling into three basic categories: space technology, space science and life sciences. They were all developed by the National Research Council of Canada and all were scheduled to be performed by Payload Specialist Marc Garneau, who represented the NRC.

2. Radiation Experiments: Two experimental dosimeters were used to monitor gamma radiation exposure to the crew: the Thermoluminescent Dosimeter and the Radiation Monitoring Equipment. They were flown primarily to evaluate them compared to the systems presently in use.

3. Auroral Photography Experiment (APE): This experiment aimed to photograph auroral activity from orbit. *Challenger's* high-inclination orbit afforded ample opportunity for such photography in the far northern and southern regions near the poles.

4. IMAX Motion Picture Camera System: Making its third and final flight on the Shuttle, footage from this large-format 70 mm motion picture camera has been assembled into a 30 minute film entitled *The Dream Is Alive.* The film can be shown only at specially-equipped

theatres because a large wrap-around screen is required some nine times bigger than a conventional screen.

Mission Day 1: 5 October 1984

The 13th flight of the programme and the sixth for *Challenger* got underway at 11:03:00 (all times are GMT) in a spectacular pre-dawn liftoff from Pad 39A at the Kennedy Space Center. Low-lying clouds hung over the pad, but *Challenger* burst through into clear, purple-blue skies within a few seconds. Visually, the liftoff was reminiscent of STS-8's first night Shuttle launch in August 1983, but this flight had the added beauty of rich twilight sky colours.

Like the STS-9/Spacelab 1 flight before, 41G was targeted for a 57° orbital inclination. This dictated a north-easterly flight azimuth out of Kennedy - a path that took *Challenger* up the eastern seaboard of the United States and out over the north Atlantic towards Europe.

The ascent was 'by the book.' Booster performance was as expected and the main engines put in another trouble-free performance. On this mission, the payload was light enough that the engines did not have to go above their normal 100% thrust level.

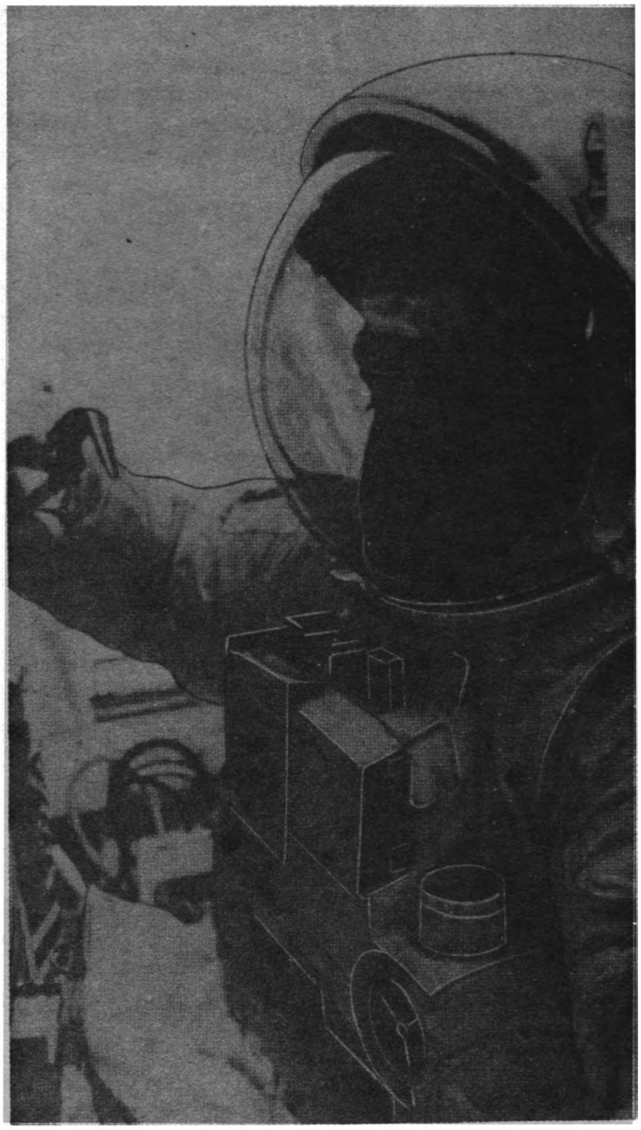
Following Orbital Maneuvering System engine burns at 11:13 and 11:49, *Challenger* was in a 352 km circular orbit, exactly the desired value.

Upon opening the payload bay doors, the crew got a look at their cargo. The folded ERBS satellite and the OSTA-3 package seemed to have come through the launch well but the astronauts did notice some damage on the two OMS pods however. During her checkout of the Remote Manipulator System (RMS) arm, Ride used its TV cameras to take a closer look. It seemed that a 1 m long strip of insulation had peeled away from the starboard pod and one of the tiles appeared chipped on the port one. Controllers in Mission Control Center-Houston were not concerned, however. The areas were not expected to endure high heat loads during entry.

The main order of the day for *Challenger's* crew was the deployment of ERBS. Sally Ride was primarily responsible for setting it loose, which she planned to do during *Challenger's* sixth orbit at about 19:33, but she had a busy series of checks and tests to complete on the satellite first. She began by powering the satellite up at about 13:30 so that Goddard Space Flight Center controllers could check the spacecraft while it was still inside the bay. She then used the arm to lift the craft out of the bay and suspend it high over *Challenger*. There more checks were made before Goddard gave a 'go' for solar array deployment. When the command was given, however, the two 2.7 x 3.7 m panels did not move. More deployment commands were sent both by the astronauts and the ground controllers without success. Ride even used the arm to gently shake the satellites in the hope that it would deploy the panels, but nothing seemed to work. By this time, it was beginning to look as though ERBS would have to be put back in the bay for return to Earth. The satellite would be useless without the electrical power generated by the arrays.

Additional study of the telemetry seemed to indicate that the panel hinges were probably frozen shut. Pursuing the theory, ERBS was turned so that the Sun could warm up the deployment mechanism. After a short while, the panels unfolded one at a time like great butterfly wings, locking securely into place. There was now nothing standing in the way of the satellite's release. After positioning it in the proper attitude, Ride commanded the robot arm to let go. Release came at 22:18 - nearly three hours late. ERBS was flying free, and *Challenger* slowly backed away, leaving it on its own.

Long burns of ERBS' own hydrazine thrusters on 7, 8 and 9 October were used to boost the spacecraft from *Challenger's* 352 km orbit up to its operational path 611 km high. By 10 October, ERBS was on station in good health, ready to begin its energy measurement mission.



Dave Leestma photographed in close-up working on the refuelling test. *NASA*

With the main work of the day behind them, the crew began preparing for their first sleep period. But, before they could bed down, a problem was noticed with *Challenger's* Ku-band dish antenna. The astronauts found that it could not be commanded to track the TDRS satellite properly. While the problem did not affect communications with Mission Control through the satellite, it posed a very serious threat to the SIR-B experiment, which had to transmit to TDRS through the Ku-band dish for full success.

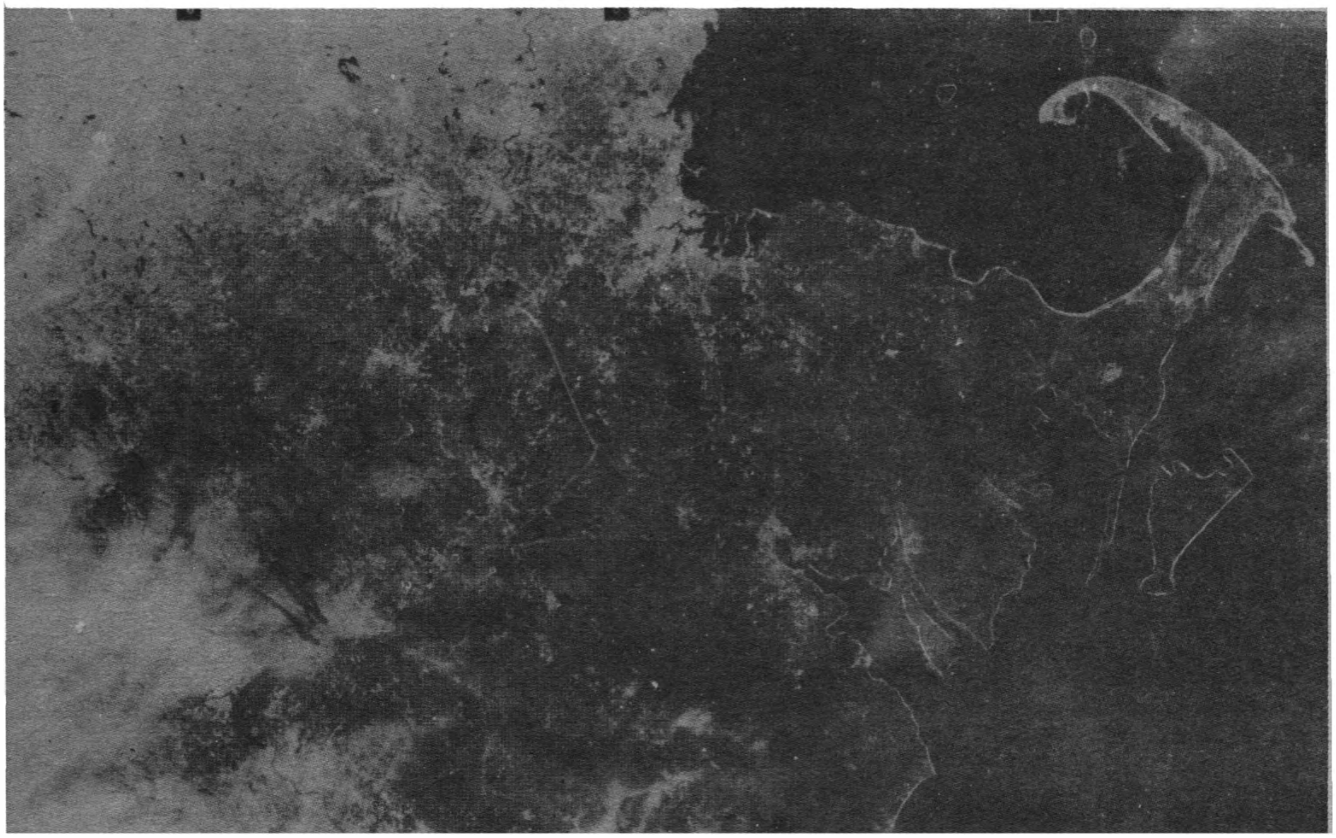
As the problem occurred so late in the day, it was decided to have the astronauts look into the matter in greater detail on Day 2 after a good night's sleep.

Mission Day 2: 6 October 1984

Most of Day 2 was taken up with solving the problem of the antenna. Since SIR-B operations had to be suspended until it was repaired, a special urgency was placed on the work.

After trying a number of procedures designed to get the dish to stop its slewing and rolling motion, the

An SIR-B radar image of the Ganges flood plain in Bangladesh. It is hoped that radar images will help in detecting areas of standing water - breeding grounds for malaria-carrying mosquitoes. The scale is about 3.5 km/cm. *NASA*

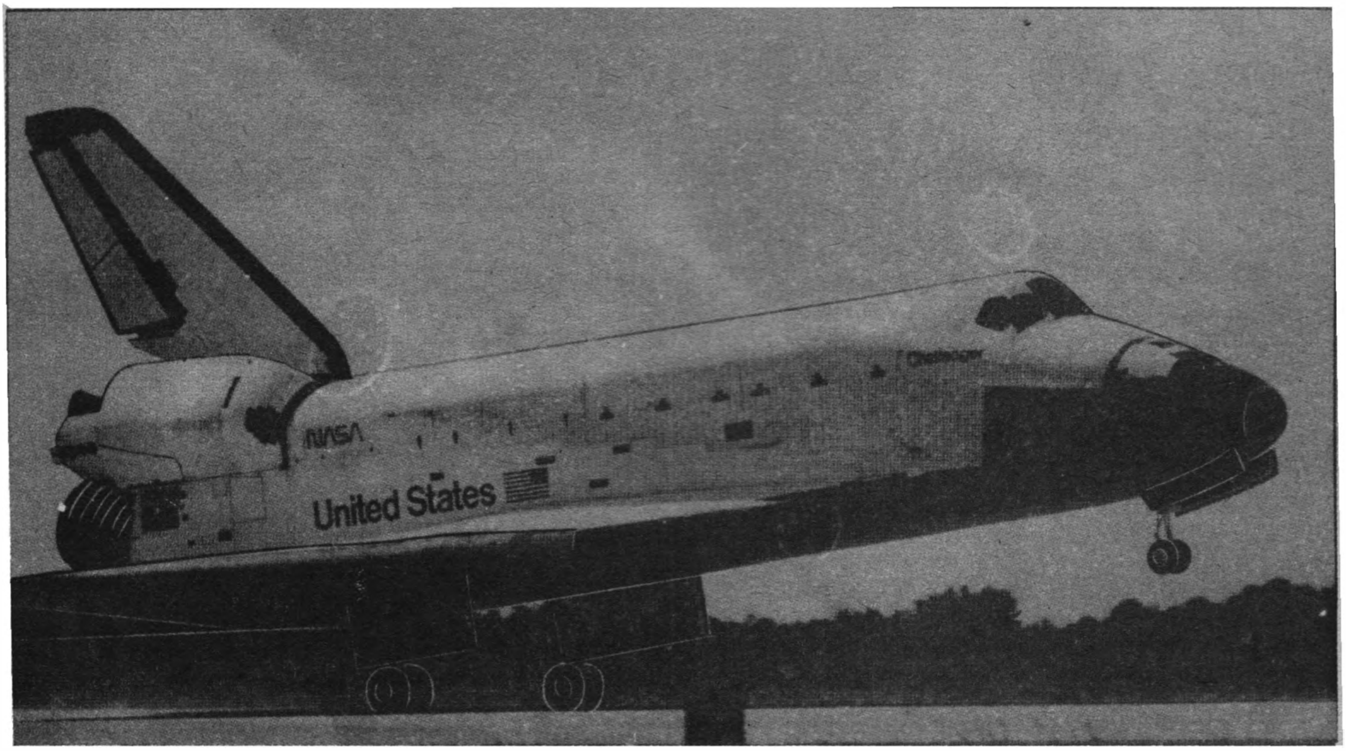


An image from the Large Format Camera, covering Massachussetts, Connecticut, Rhode Island, New Hampshire and Vermont in the US. The scale is 1:1.78 million. *NASA*

astronauts used the best option available to them: they 'pulled the plug' on the antenna's drive, thereby locking the dish into an orientation that would allow the Orbiter itself to point the antenna at the TDRS satellite. The plan was that the crew would run SIR-B for short intervals, storing the data on the limited supply of on-board tape. They then would turn *Challenger* to aim the dish at TDRS in order to dump the tape to the ground. While the procedure was considered workable, it was still expected to result in a serious reduction in data.

Meanwhile, the crew also began having minor troubles with the SIR-B antenna itself. The array was designed to fold up mechanically and latch shut when it was not in use. The crew was able to fold it, but the latches refused to catch. Thus, the astronauts faced a dilemma. No major manoeuvres (and there were two scheduled) could be performed with the antenna flopping about in the bay. Once again, the trusty robot arm came to the rescue. Under the expert control of Sally Ride, it was used to nudge the antenna gently in such a way that the latches closed tightly.

Day 2 was not all trouble, though. Operations with the Large Format Camera began early and went smoothly. Sullivan and Leestma successfully transferred a quantity of hydrazine from one tank to another using computer keyboards on the aft flight deck to send commands to the ORS. The plumbing seemed tight and pressures were all within normal limits. The astronauts also performed a pair of OMS burns to lower their orbit to 274 km. This was the first step in a two-stage manoeuvre to lower the orbit to 226 km for most of the rest of the mission. The lower orbit was desired to permit maximum benefit from



The second Shuttle landing at KSC.

the various Earth sensors on board. The second set of OMS burns was scheduled for early on Day 3.

Mission Day 3: 7 October 1984

After lowering their orbit to 226 km, the crew got to work on salvaging as much as they could from the SIR-B mission. The scheme to manoeuvre the Orbiter to track TDRS worked well, and good digital radar data were received on Earth. But problems were still encountered whenever the astronauts tried to latch the radar antenna shut. In light of this, it was decided to postpone Leestma's and Sullivan's EVA from Day 5 until Day 7. SIR-B operations were expected to be completed by then, and the two spacewalkers could then manually latch the antenna shut, making sure that everything was secured for entry. There were also plans to have the two spacewalkers stow the unpowered Ku-band antenna manually.

Later in the day, television pictures were sent to Earth showing Canada's first astronaut, Payload Specialist Marc Garneau, performing some of the space adaptation syndrome experiments that were part of the CANEX investigations. In one test, called 'The Vestibulo-Occular Reflex Experiment,' he attempted to aim the beam of a flashlight at a target on a wall while blindfolded.

41G's other passenger, oceanographer Paul Scully-Power, was also very busy. Extremely excited about his high-altitude vantage point, he observed and tracked eddies in the Indian Ocean and took some hand-held camera photographs of an oil spill in the Gulf of Oman.

Mission Day 4: 8 October 1984

The flight (now being dubbed 'Murphy's Mission' by some observers) hit more snags on Day 4. First, and most seriously, communications with TDRS were knocked out for nearly 14 hours when procedural errors on the ground sent the large satellite on a slow roll through the skies. Engineers initially thought that TDRS' troubles had been caused by a cosmic ray 'hit,' something that happens occasionally to the satellite, but later information showed that human error at the TDRS control centre in White Sands, New Mexico was at fault. The problem was not corrected until about 02:00 on 9 October (after the astronauts had gone to sleep) so, during Day 4, the crew was forced to rely on conventional ground stations for all contact with Mission Control. As another consequence, data runs using SIR-B were impossible, putting that work still further behind schedule.

As if the emotional irritation of the TDRS difficulties were not enough, the astronauts also became physically uncomfortable. After an ice ball clogged the plumbing in *Challenger's* water spray boiler system, the cabin temperature soared to 35°C. Crippen compared it to 'late August in Houston' as he and his six crewmates sweltered in the crowded confines of the stuffy cabin.

It was also beginning to look as though Mother Nature, too, was out to get Mission 41G. A large tropical storm, dubbed 'Josephine', was brewing in the Atlantic off Florida. At this early stage, it was too soon to tell if the storm would interfere with *Challenger's* landing at the Kennedy Space Center, but NASA meteorologists began keeping a close eye on it just the same.

Mission Day 5: 9 October 1984

Awakened to the theme music from the film *Rocky*, mission commander Crippen immediately noticed that Mission Control was communicating through TDRS. 'You guys got your satellite fixed!' he noted with elation.

De-icing efforts on the water spray boiler system were also successful and, before long, cool air was flowing into *Challenger's* cabin.

In the morning, the astronauts packed themselves into the mid-deck for a televised space-to-ground press conference. Marc Garneau and Paul Scully-Power were asked about their research, Dave Leestma and Kathy Sullivan were questioned about their imminent EVA, and Bob Crippen was asked whether seven people jammed into the Orbiter was creating any problems. He replied that 'if people are properly disciplined, we can operate with seven people in the Space Shuttle.' He further said that he believed that the trouble-free operation of the Orbiter's toilet on this mission was making things easier.

The toilet has had a history of being one of the most difficult pieces of equipment on the Shuttle, suffering malfunctions on every single flight to date. On 41G, however, it worked perfectly.

Also during Day 5, tropical storm Josephine was upgraded to 'Hurricane' status, and the monitoring of its position and predicted path intensified.

Mission Day 6: 10 October 1984

Most of the day was occupied by preparations for the EVA. Sullivan and Leestma, assisted by McBride, checked the pressure suits by donning the garments and pumping them up to 0.3 kg/cm^2 (4 psi) pressure. Everything went well and the suits were pronounced ready for the spacewalk.

In addition to their programmed tasks for the EVA, Sullivan and Leestma were also being asked to see what they could do to stow both the SIR-B and Ku-band antennae for entry. Although both jobs were expected to be fairly simple, the astronauts were prepared for trouble. For example, if the SIR-B antenna failed to latch shut even with manual assistance, they planned to use a sleeping bag to tie the antenna down. If the antenna were left to flow about during entry, it could easily do damage to the Orbiter's payload bay doors and radiators.

Mission Day 7: 11 October 1984

History was made at 15:46 as Dr. Kathryn Sullivan floated through the airlock hatch into the payload bay to become the first American woman and only the second woman in history to walk in space. Her partner, David Leestma, had gone outside just four minutes earlier to start the 3.5 hour excursion.

They first turned their attention to the main task: the re-fuelling work with the ORS. Leestma went directly to the aft end of the bay to the hydrazine equipment and was later joined by Sullivan, who first stopped at an equipment locker to pick up a tool caddy.

Leestma did the bulk of the refuelling work, with Sullivan acting as a 'plumber's assistant' by handing him tools and documenting his progress with photographs. Leestma found that connecting the fuel lines to the simulated Landsat panel was much easier than in the ground simulations. The valves penetrated easily and pressure tests of the connection disclosed no leaks. The final test would come after the astronauts were back inside *Challenger* and they made their first attempt to transfer fuel through their plumbing job.

Next on the agenda was the latching of the SIR-B antenna and the stowing of the Ku-band dish, both of which came off without problems. Following some spectacular sightseeing and payload bay acrobatics, commander Bob Crippen called the two astronauts back inside. The airlock was repressurised and they doffed the suits after a very successful day.

Mission Day 8: 12 October 1984

The last full day in space was taken up almost entirely by preparations for entry and landing. Pilots Crippen and McBride conducted a thorough checkout of *Challenger's* Flight Control System to ensure that all was ready, while Mission Specialists Ride, Sullivan and Leestma and Payload Specialists Scully-Power and Garneau completed the last of the experiments before packing equipment and notebooks into mid-deck lockers.

The crew made time to take the traditional telephone call from President Reagan, who congratulated them on the successful mission despite all of the problems encountered.

Landing plans were still on for the Kennedy Space Center, with Hurricane Josephine posing no threat. Weather predictions for the Florida side were good, and everything seemed to be on target for a scheduled landing at 16:26 on 13 October.

Mission Day 9: 13 October 1984

As 13 October dawned it appeared as though Robert Crippen, thwarted in two previous attempts to land *Challenger* at the Kennedy Space Center, was at last going to get his chance. The weather was excellent with scattered cirrus clouds at 8000 m and 18.5 km/hr surface winds with gusts to 28 km/hr. Everything was ready.

The OMS deorbit burn was made successfully near Australia just as *Challenger* was ending its 132nd orbit. The 143 second manoeuvre eliminated 81.5 m/s from the Orbiter's speed, setting it up to hit the atmospheric entry point over the Pacific some 7980 km uprange from Kennedy at an altitude of 122 km.

The 57° inclination gave *Challenger* unusual entry groundtrack. Heading northward over the Pacific, the Orbiter crossed the Alaskan coastline before heading back southward across Canada and the mid-western United States. Descending from 68 to 40 km and decelerating from Mach 22 to Mach 6, *Challenger* flew over or near the cities of Winnipeg, Duluth, Milwaukee, Indianapolis, Cincinnati, Knoxville and Atlanta. There were no confirmed sightings of the Orbiter from the ground, but pilots Crippen and McBride had an excellent high-speed, low-level view as they crossed the US from north to south in less than seven minutes.

Finally, *Challenger* arrived in the sky over the Kennedy Space Center, announcing its arrival with the customary double sonic boom. Crippen flew the Orbiter through a 190° left turn to line it up with Runway 33, as thousands of spectators watched from the ground.

The giant space bird eased out of the sky and, at 16:26:34, the main landing gear wheels touched the concrete runway surface, giving off a brief puff of smoke. Flight time was 8d 5h 23 m 34 s.

DO YOU REMEMBER?

25 Years Ago...

1 April 1960. Television Infra-red Observation Satellite 1 (Tiros 1), the first meteorological satellite, is launched. Built by RCA, the satellite operated for 89 days and demonstrated the feasibility of using satellites for weather observations.

20 Years Ago...

18 March 1965. Alexei Leonov makes the first spacewalk during the Voskhod 2 flight. The ten minute EVA took place over the USSR during Voskhod's second flight.

6 April 1965. Early Bird, the first geostationary commercial communications satellite, is launched from Cape Canaveral.

15 Years Ago...

13 April 1970. Two days after launch an oxygen tank explodes aboard the Apollo 13 service module *en route* to the Moon. The lunar landing is aborted and the crew return safely to Earth after rounding the Moon.

10 Years Ago...

15 April 1975. The establishment of the European Space Agency (ESA) is confirmed during the European Space Conference in Brussels. Briton Roy Gibson is appointed first Director-General.

5 Years Ago...

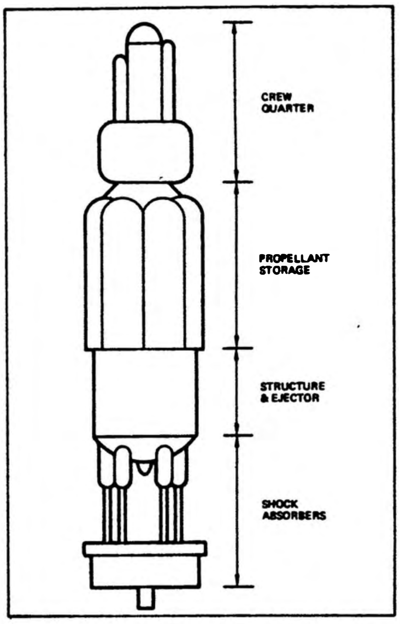
10 April 1980. Soyuz 35 with cosmonauts Popov and Ryumin aboard docks with the Salyut 6 space station. This long-stay crew carried out servicing and maintenance tasks before starting an extensive series of experiments.

K.T. WILSON

TEST YOUR SPACE KNOWLEDGE

Our two space quizzes in 1984's magazines were so popular that a third is now produced below by readers' demands. Some of the questions are easy, most have been covered in past volumes of Spaceflight, *while others will really stretch your space knowledge! Answers are at the back of this issue. Our thanks go to Keith Wilson for providing most of the questions.*

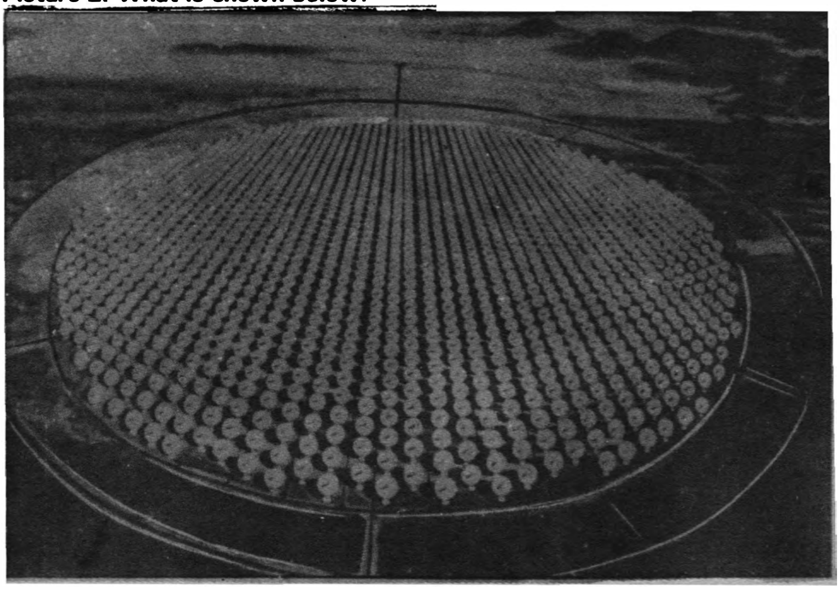
1. At one time a Mercury-Atlas 10 flight was planned. Who would have been the pilot?
2. Which US interplanetary spacecraft visited both Venus and Mercury?
3. Which satellite discovered the Van Allen radiation belts?
4. The dog Laika was carried into orbit aboard a Soviet Sputnik satellite in 1957. Which Sputnik?
5. What is the connection between the following three spacecraft? Gemini 2, Space Shuttles *Columbia* and *Challenger*.
6. Name the two Martian moons.
7. Which Apollo crew named a small lunar crater after Arthur C. Clarke's novel *Earthlight?*
8. Mariner 9 orbited the planet Mars but what happened to Mariner 8?
9. Which satellite was known as Early Bird?
10. What is a Planetary Observer?
11. Which booster launched the Voyager spacecraft in 1977?
12. Which Solar System body has the following moons in orbit around it: Sinope, Pasiphae, Carme and Ananke?
13. John Young was reprimanded after Gemini 3 for taking something extra along on the flight without permission. What was it?
14. Chryse Planitia was the landing site of which spacecraft?
15. Which US satellite, launched in May 1976, is being used to help predict Earthquakes by the use of laser ranging?
16. Which Luna spacecraft carried Lunokhod 1 to the Moon?
17. Which country has the largest share in the European launcher Ariane?
18. On which planet would you find Maxwell Montes?
19. The second Skylab crew had two spiders aboard the space station. Can you name them?
20. The first successful Venus probe was launched in August 1962. Name it.
21. Who uses the OSCAR satellites?
22. What is the primary use of the Soviet Meteor satellites?
23. In which year did President Kennedy propose that the US should establish as a national goal a manned lunar landing by the end of the 1960's?
24. In which year will the Galileo Jupiter craft be launched?
25. How many astronauts have flown in spacecraft named *Columbia* up to the end of December 1982?
26. Mariners 11 and 12 had their names changed. To what?
27. Sweden's first satellite is due to be launched in 1985. What is it called?
28. Who flew the Soyuz 1 mission?
29. In which European city are the headquarters of INMARSAT?
30. Which is Saturn's largest satellite?



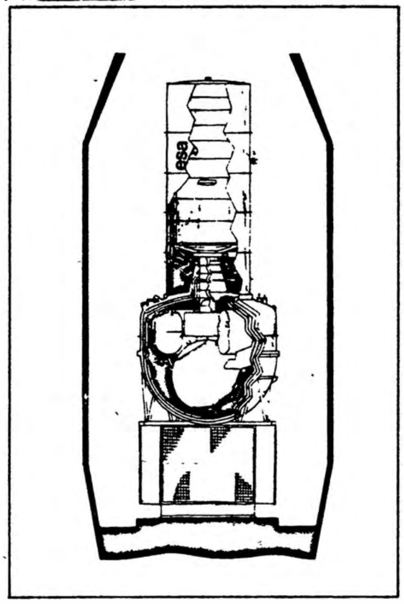
Picture 1. What is this concept?

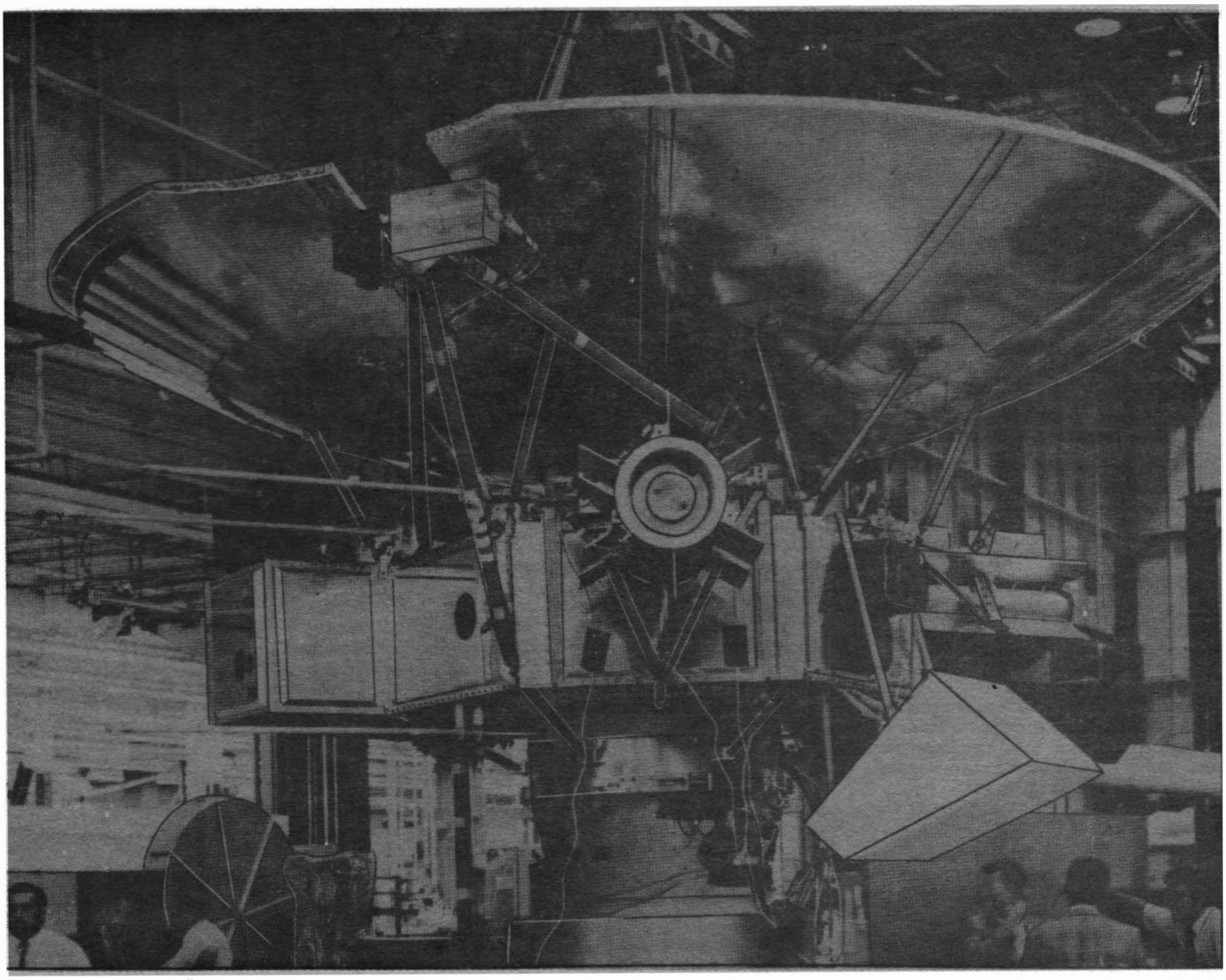
31. Which Gemini crew had 'Eight days or bust' on their crew patch?
32. When will the US Venus VRM probe be launched?
33. SMM was designed to observe which Solar System body?
34. Which spacecraft was the first to send a picture to Earth from the surface of another planet (our Moon excluded)?
35. SPAS flew free from *Challenger* on STS-7. What do the letters SPAS stand for?
36. The crater Kuiper is a prominent ray-crater on which planet?
37. In what year was the Space Shuttle programme approved?
38. Which satellite will be the first to encounter a comet?
39. What was special about Cosmos 1445?
40. What do the letters SETI stand for?

Picture 2. What is shown below?



Picture 3. What is this?

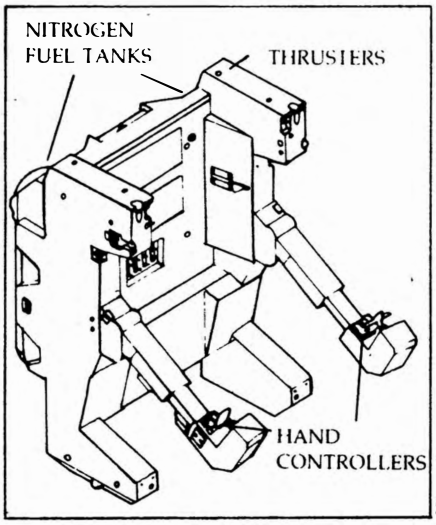




Picture 4. What is this?

41. In which South American country is ESA's Ariane launch centre?
42. Around which planet was a ring system discovered in March 1977?
43. Who performed an EVA from Apollo 9's lunar module in Earth orbit?
44. Which BIS Fellow proposed in 1981 that a manned Mars mission could take place in 1995?
45. The NOSL experiment has been flown on a number of Space Shuttle flights. What was it designed to observe?
46. Why was Cosmos 954 in the news in 1978?
47. Which was the first satellite into polar orbit?
48. What was Landsat 1 called when launched?
49. What did astronauts Shepard and Mitchell use the MET for during the Apollo 14 mission in 1971?
50. What was the name of the Cuban cosmonaut who visited Salyut 6 in September 1980?
51. What are the *UTC Liberty* and *UTC Freedom* used for?
52. Which US company built the Lunar Roving Vehicle?
53. What was the 1971 'Cyclops' proposal?
54. Who was the late addition to the STS-7 crew?
55. List all the signatures on the Apollo 11 Lunar Module plaque.
56. Which Apollo Saturn V was struck by lightning during launch?

Picture 5. What is this?



57. Which Space Shuttle has the official number 099?
58. Which country plans to launch Maritime Observation Satellite 1?
59. What was the name of the US manned space project which was cancelled in June 1969?
60. What was the first manned spacecraft to orbit the Moon?
61. Who was the first man to fly solo around the Moon?
62. When will Halley's comet next reach perihelion?
63. How many probes will approach it?
64. Who was the first black US astronaut to fly?
65. Name the first three women to fly in space.
66. Why did the Soyuz T-8 cosmonauts not occupy Salyut 7?
67. What was the first man-made object to reach the lunar surface?
68. Which star was first observed to possess a ring of material?
69. Which satellite made the observation?
70. What is the origin of the name of the Agena upper stage?

SATELLITE DIGEST - 182

Robert D. Christy

Continued from the March issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

SPACENET 2 1984-114A, 15385

Launched: 0114*, 10 Nov 1984 from Kourou by Ariane 3 (V11).
Spacecraft data: Box-shaped structure, 1.62 m x 1.32 m x 0.99 m, with a 14.33 m span, two panel solar array. The satellite is three-axis stabilised using a bias momentum system, and station keeping is by hydrazine thrusters. The mass in orbit is 705 kg, including fuel.
Mission: Commercial communications satellite covering the continental United States and using C-band (6/4 GHz) and Ku-band (14/12 GHz).
Orbit: Geosynchronous above 69° W.

MARECS B2 1984-114B, 15386

Launched: 0114*, 10 Nov 1984 from Kourou by Ariane 3 (V11).
Spacecraft data: Hexagonal prism body, 2 m across and 2.5 m long, with power provided by a 13.8 m span, two panel solar array. Stabilisation is by momentum wheels and station keeping is by hydrazine thruster. The mass in orbit is 563 kg, including fuel, reducing to 488 kg on fuel depletion.
Mission: Replacement for Marecs B which was lost when the Ariane L5 vehicle malfunctioned at launch on 1982 Sep 10. The satellite carries a maritime communications package leased from ESA by Inmarsat, using C-band for satellite to ground links, and L-band (1.6 GHz) for ship to satellite links. The satellite's L-band receiver includes an emergency search and rescue beacon locator.
Orbit: Geosynchronous above 177.5° E.

NATO 3D 1984-115A, 15391

Launched: 0034*, 14 Nov 1984 from Cape Canaveral AFB by Delta.
Spacecraft data: Cylinder, 2.2 m long and 2.2 m diameter, spin stabilised. The mass in orbit is about 320 kg.
Mission: Fourth NATO 3 series military communications satellite, replacing one of the earlier three.
Orbit: Geosynchronous above 138°W.

COSMOS 1608 1984-116A, 15393

Launched: 0740, 14 Nov 1984 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and a cylindrical supplementary payload at the forward end. Length 6 m, max diameter 2.4 m and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered or re-entered after 33 days.
Orbit: 195 x 250 km, 89.01 min, 69.97° manoeuvrable.

COSMOS 1609 1984-117A, 15395

Launched: 1220, 14 Nov 1984 from Plesetsk by A-2.
Spacecraft data: Similar to Cosmos 1609.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 414 km, 92.30 min, 72.85°.

COSMOS 1610 1984-118A, 15398

Launched: 0640, 15 Nov 1984 from Plesetsk by C-1.
Spacecraft data: Cylinder with domed ends, enclosed in a drum-shaped solar array with length and diameter both about 2 m, and mass around 700 kg.
Mission: Navigation satellite.
Orbit: 968 x 1013 km, 104.97 min, 82.95°.

COSMOS 1611 1984-119A, 15403

Launched: 1030, 21 Nov 1984 from Tyuratam by A-2.
Spacecraft data: Similar to Cosmos 1609.
Mission: Military photo-reconnaissance.
Orbit: 173 x 351 km, 89.76 min, 64.75° manoeuvrable.

COSMOS 1612 1984-120A, 15406

Launched: 1425, 27 Nov 1984 from Plesetsk, possibly by F vehicle.
Spacecraft data: Possibly a cylindrical body with two Sun-seeking solar panels, length about 5 m and diameter about 1.5 m. The mass is around 2200 kg.
Mission: Probably intended as a replacement for Meteor 2(8), 1982-25A. The launch vehicle failed to shut down at perigee, thus preventing achievement of a 950 km, circular orbit.
Orbit: 324 x 1341 km, 102.56 min, 82.61°.

COSMOS 1613 1984-121A, 15414

Launched: 1400, 29 Nov 1984 from Plesetsk by A-2.
Spacecraft data: Similar to Cosmos 1609.
Mission: Military photo-reconnaissance, recovered after 25 days.
Orbit: Initially 197 x 356 km, 90.08 min, 72.85°, then manoeuvred on 10 Dec to 356 x 414 km, 92.31 min, 72.84°.

1984-122A 15424

Launched: (1830?), 3 Dec 1984 from Vandenberg AFB by Titan 3D.
Spacecraft data: Cylinder, about 15 m long and 3 m diameter with mass around 13000 kg.
Mission: Reconnaissance using TV imaging, KH-11 type satellite.
Orbit: Approx 250 x 520 km, 92.2 min, 97° manoeuvrable.

NOAA 9 1984-123A, 15427

Launched: 1042, 12 Dec 1984 from Vandenberg AFB by Atlas.
Spacecraft data: Box-shaped, approx 4 m long and 2 m diameter, and with a single solar panel at one end. The mass is around 1700 kg.
Mission: Meteorological satellite.
Orbit: 844 x 865 km, 102.09 min, 98.92°.

MOLNIYA-1(63) 1984-124A, 15429

Launched: 2041, 14 Dec 1984 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with conical motor section at one end, deriving power from a 'windmill' of six solar panels. Length 3.4 m, diameter 1.6 m, and mass 1800 kg approx.
Mission: Communications satellite providing telephone, telegraph and television links through the 'Orbita' system.
Orbit: Initially 452 x 40847 km, 737.01 min, 62.85°, then lowered to 453 x 39904 km, 717.82 min, 62.83°, to provide daily ground track repeats.

VEGA 1 1984-125A, 15432

Launched: 0916, 15 Dec 1984 from Tyuratam by D-1-E.
Spacecraft data: Cylindrical with diameter (max) about 2.5 m, and length about 3 m, at one end is a 3 m diameter aeroshell containing a Venus lander and atmospheric balloon package. At the opposite end is a moveable scan platform for Halley's comet fly-by experiments. The mass is around 4000 kg.
Mission: Joint Venus lander/fly-by and Halley's comet fly-by. At Venus encounter in Jun 1985, the atmospheric entry vehicle will carry a Soviet-built surface lander into Venus' atmosphere, and will release a French-built balloon (4 m diameter) during descent which will float at about 44 km above the surface, returning meteorological data from an attached probe. The close approach to Halley's comet is due during Mar 1986.
Orbit: Heliocentric.

COSMOS 1614 1984-126A, 15442

Launched: 0355, 19 Dec 1984 from Kapustin Yar by C-1.
Spacecraft data: Delta-winged vehicle, about 3.5 m long and 2.5 m span, mass around 1000 kg.
Mission: Spaceplane recovery test, landed in the Black Sea after one orbit, mission length around 110 minutes.
Orbit: 176 x 223 km, 88.41 min, 50.67°.

COSMOS 1615 1984-127A, 15446

Launched: 1302, 20 Dec 1984 from Plesetsk by C-1.
Spacecraft data: Not available.
Mission: Military, possibly radar calibration.
Orbit: 440 x 499 km, 93.99 min, 65.84°.

DESIDERATA

The Library Committee is seeking the following books for the Society's Library. Any member who can help is urged to contact the Executive Secretary.

A.L. Lowell	Biography of Percival Lowell	Macmillan Co., 1935
F. Bailey	An account of the Revd. J. Flamsteed	Dawsons, 1966
A. & P. Bear	Kepler - 400 years	Pergamon, 1975
H.M. David	Wernher von Braun	Putnam & Sons, 1967
J.L.E. Dreyer	Tycho Brahe	Dover, 1963
M. 'Espinasse	Robert Hooke	Univ. of Calif., 1956
E.G. Forbes	The Gresham Lectures of Jon Flamsteed	Mansell Pub. Ltd, 1975
J. Kepler	Somnium (Trans)	Univ. of Wisconsin Press, 1967
F.E. Manuel	Portrait of Isaac Newton	Harvard Univ. Press, 1968
L.T. More	Isaac Newton	Dover, 1962
C.A. Ronan	Astronomers Royal	Doubleday, 1969
H.J. Steffens	The Devpt. of Newtonian Optics in England 1977	Neale Wats on Academic
H.B. Walters	Wernher von Braun - Rocket Engineer	Macmillan, 1964
R.S. Westman	The Copernican Achievement	Univ. of Calif., 1975
I.B. Cohen	Newton's Theory of the Moon's Motion	Academic Pubs., 1975
T von Oppolzer	Canon of Eclipses	Dover, 1962
H. Woolf	The Transits of Venus	Princeton Univ. Press (or Arno Press), 1959
A.J. Meadows	Early Solar Physics	Pergamon, 1970
J.P. Nichols	The Planet Neptune	John Johnstone
Y Ohman, ed.	Mass Motions in Solar Flares and Related Phenomena	MacMillan, 1968
H. Zirin	The Solar Atmosphere	Blaisdell Pub. Co., 1966
W. Ley	Visitors from Afar - The Comet	McGraw Hill, 1969
J. Mascart	Le Comete de Halley	Gauthier-Villars, 1911
C.P. Olivier	Comets	Williams & Wilkins, 1930
P.L. Brown	Comets - Meteorites	Taplinger, NY, 1974
A.H. Delsemme	Comets, Asteroids, Meteorites	Univ. of Toledo Press, 1977
C.D. Hellman	The Comet of 1577 - its Place in the History of Astronomy	AMS Press (or Columbia Univ. Press), 1944
G.P. Kuiper & E. Romerner	Comets: Scientific Data & Missions	Univ of Arizona Press, 1972
V.F. Buchwald	Handbook of Iron Meteorites	Univ. of Calif. Press, 1975
S. Drake & C.D. O'Malley	The Controversy of the Comet of 1618	Univ. of Penn Press, 1960
E.L. Krinov	Giant Meteorites	Pergamon Press, 1966
B. Mason	Meteorites	J. Wiley, NY 1962
H.H. Nininger	Arizona's Meteorite Crater	World Press, Denver, 1956
R.S. Richardson	Getting Acquainted with Comets	McGraw-Hill, 1967
H. Jeffers & W. Van de Bos	Index Catalogue of Visual Double Stars	Lick Observatory, 1963
J.W. Sulentic & W.G. Tifft	Revised New General Catalogue of Nonstellar Astronomical Objects	Univ. of Arizona, 1973
E.W. Downs, Ed.	The US Air Force in Space	Praeger, 1966
A. McIntyre	Summary of AFCRL Rocket & Satellite Experiments (1946-1966)	AF Cambridge Research Laboratories, 1966
	Space Handbook. Maxwell Air Force Base	Air University Revised annually
E. Abel	The Missile Crisis	Lippincott, 1966
J. Baar & W.E. Howard	Combat Missilemen	Harcourt, 1961
E. Bergaust	Rockets of the Armed Forces	Putnam, 1966
E.M. Bottome	The Missile Gap	Fairleigh Dickinson Univ., 1971
B. Collier	The Battle of the V-Weapons	Morrow, 1965
W. Dornberger	Nuclear Flight: The United States Air Force Programs for Atomic Jets, Missiles & Rockets	Duell, 1960
W. Dornberger	The United States Air Force Report on the Ballistic Missile: Its Technology, Logistics & Strategy	Duell, 1960
C. Gurney, Ed.	Rocket & Missile Technology	Watts, 1964
M. Hunter	The Missilemen	Doubleday, 1960
R. Neal	Ace in the Hole: The Story of the Minuteman Missile	Doubleday, 1962
S. Ulanoff	Illustrated Guide to US Missiles & Rockets	Doubleday, 1962
USAF Missile Develop. Center	History of Research in Space Biology & Biodynamics	Holloman AFB, 1959
S.W. Smith	A Handbook of Astronautics	Univ. of London Press, 1967
J. McGovern	Crossbow and Overcast	Morrow & Co, 1964
B. Kit & D.S. Evered	Rocket Propellant Handbook	MacMillan, 1964
K.F. Gantz, Ed.	Men in Space: The United States Air Force Program for Developing the Spacecraft Crew	Duell, 1959
J.J. Haggerty	First of the Spacemen	Duell, 1960
R. Hirsch & J.J. Trento	The National Aeronautics and Space Administration	Praeger, 1973
M.M. Link	Space Medicine in Project Mercury	
F. Golden	Colonies in Space: The Next Giant Step	Harcourt Brace & Javanovich, 1977

SCIENCE MUSEUM VISIT

25 members who participated in the Science Museum visit on the evening of 4 December last were in for a good time. Not only did they have the run of the Space and Telecommunications sections but the use of the Lecture Theatre and an evening meal to boot.

The Executive Secretary, who played Host to the assembly, introduced John Becklake, who pointed out that the origin of the Science Museum actually went back to the great Exhibition of 1851. When that closed, the scientific and educational exhibits were transferred to the South Kensington museum (now known as the Victoria and Albert museum), but as the art collection increased they were squeezed out and so arrived at their present site. The Science Museum, with its very modern library close by, displays exhibits in over 120 different collections. The Space Exploration area, adjacent to two sections on Underwater Exploration and Remote Sensing, is one of the most modern. The space collection has never had a gallery of its own but, with more space exploration underway, it is growing fast. Even without the aid of major exhibits stored in hangars at Wroughton, the section is chafing for space. However, in nine months the Exploration Gallery will close and reopen again, in late 1986, as a new Space and Science and Technology section with an area of about 1,100 m². Among the rockets still awaiting display are a V2 (one of the best-preserved in the world), a Scout and a variety of UK missiles and research rockets (plus the Black Arrow launcher) which, altogether, probably make up the most comprehensive space collection available anywhere outside the USSR and USA.

Peter Turvey, the Space Curator, displayed with obvious pride a Congreve rocket with gas vents in the front. It had no stick but metal vanes instead and the mark 'Made and fired at Woolwich 24 December 1817.' He also displayed a box of four miniature Congreve rockets, probably made in connection with Sir William's 1823 patent. These are to form part of a new Congreve collection.

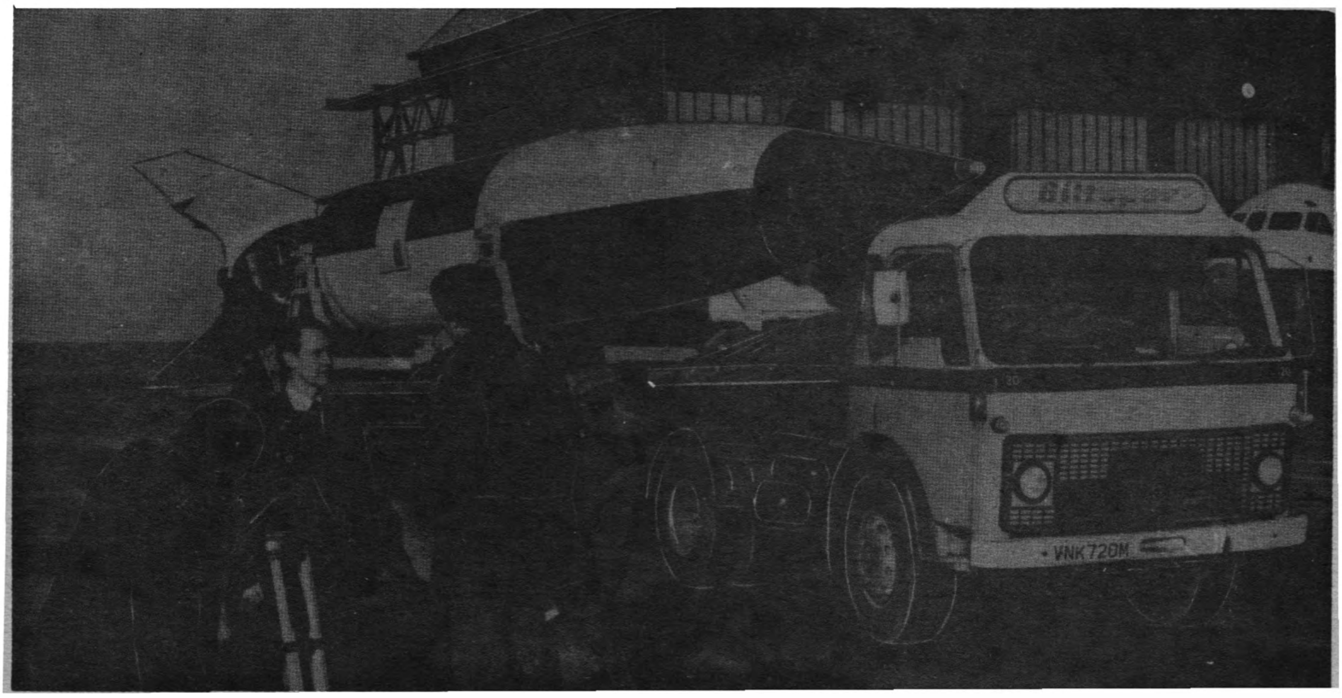
Several other museums were mentioned as useful for visit by those wishing to see more rocket and space artefacts. For example, RAF Cosford has the finest collection of German wartime rockets anywhere in the world. These originally came to the Royal Aircraft Establishment just after the war and, after a short display at the Science Museum, went first to the Rocket Propulsion Dept., at Westcott, before finally ending up at Cosford. The Rotunda, at Woolwich, is also notable for its collection of Congreve, Hale and Boxer rockets, and includes the only known examples of the Indian rockets used against the British in the 1790's.

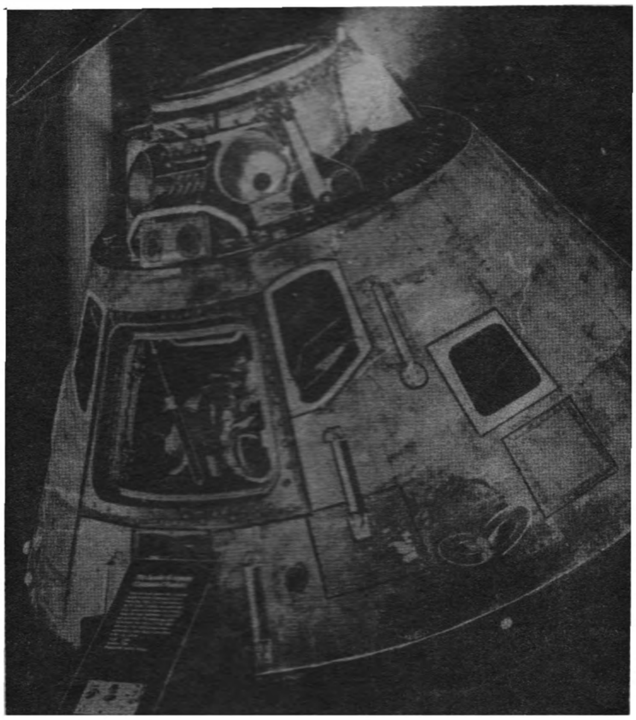
The Armagh Planetarium and the Royal Scottish Museum also have valuable space collections. Abroad, the Deutsches Museum at Munich is famous for its collection of pre-war solid rockets while, surprisingly, many Australian museums are to the fore (presumably owing to their proximity to Woomera) in containing significant missile collections.

The party then adjourned to a buffet-style dinner, with wine, arranged by courtesy of the BIS staff, which was not only attractively presented but which went down well on all counts.

The remainder of the evening was spent, pleasantly, wandering among the exhibits, looking at videos, chatting in groups and occasionally returning for 'refills,' with John Becklake and his staff on hand to talk about both the

Dr. John Becklake with the Science Museum's example of a V2, one of the best-preserved in the world. It is not presently on display at the Museum but will be added within two years. *Science Museum*





The Apollo 10 command module, 'Charlie Brown,' is a star attraction at the Science Museum. In 1971 the spacecraft went on a tour of Britain, calling in at places such as Liverpool and Sheffield.

exhibits and practically any other space-related theme one cared to mention.

The meeting ended with a promise that arrangements would be made to hold a similar event again as soon as the new Gallery had been officially opened.

AWARDS FOR IRAS TEAM

Following the success of the Infrared Astronomical Satellite mission and the release of the first infrared sky catalogue from the satellite, NASA has presented a number of awards to the IRAS team, including some BIS members. At a ceremony held on 13 December last at the Rutherford Appleton Laboratory, UK members of the project received their awards from NASA Administrator James Beggs.

Individual Public Service Medals were presented to Dr. Eric Dunford (UK Project Manager), Dr. Peter Clegg (Leader of the Resident Astronomers Team) and to Mr. Alan Rogers for his contribution to the development of the UK ground control centre. Group Achievement Awards were made to the Joint Infrared Science Working Group and to the Rutherford Appleton Laboratory IRAS operations team. Prof. R.E. Jennings represented the Science Working Group and the operations team award was collected jointly by Mr. H. Bevan and Dr. R. Holdaway. Included in the citation for the operations team were Dr. Holdaway (a *JBIS* editor) and BIS Fellow Dr. John Davies, discoverer of the IRAS comets.

Following the presentations, Mr. Beggs presented a short lecture on NASA's plans for the Space Station and answered questions from the press.

THE YEAR WE MAKE CONTACT

Our President, A.T. Lawton, represented the Society in mid-January at a special preview of *2010*, the sequel to *2001: A Space Odyssey* and based on Arthur C. Clarke's novel. Here is Mr. Lawton's personal view of the film:

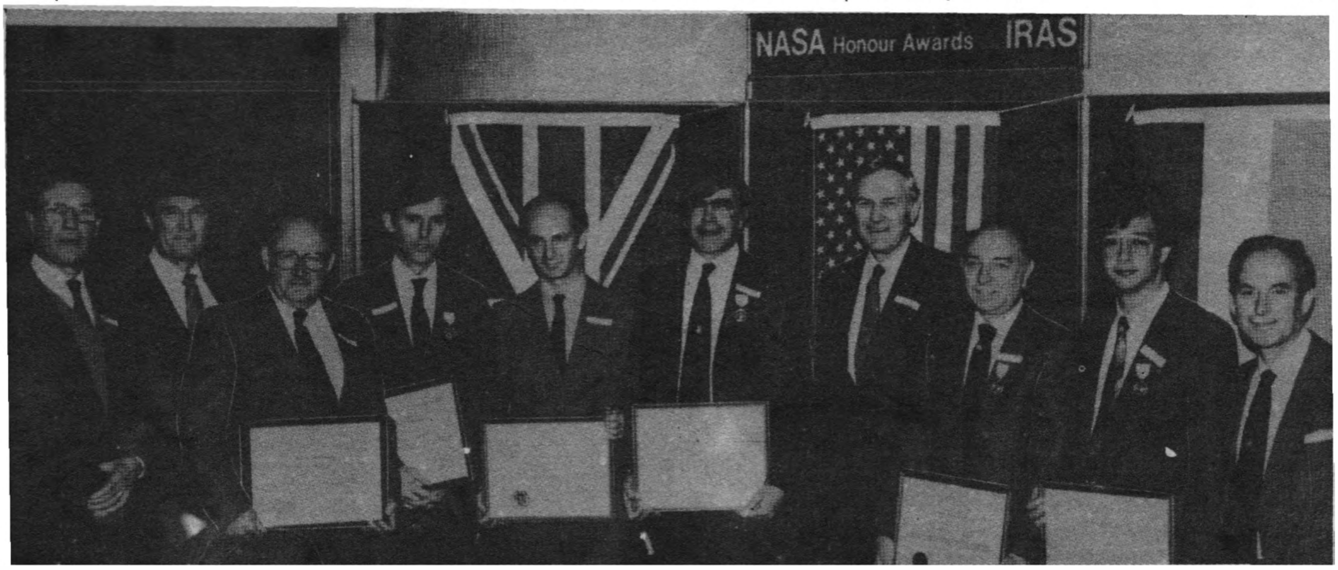
"This is one of those rare instances where the sequel is much better than the original story. The film brings the sequel novel to life in a manner that is totally convincing and humanly realistic. For this one has to thank Peter Hyams, who wrote the screenplay and then produced and directed the film. He has grasped the heart and meaning of the novel. *2001* emphasised the coldness of hard core technology and was difficult to understand. *2010* concerns *people* and how they react to various circumstances, culminating in the realisation that the human race is not alone.

"The visual effects and sound accompanyments are both stunning and realistic and in several instances one has the feeling of 'looking in' in true three dimensional viewing. This is due to meticulous attention to modelling detail and perspective.

"Look out for the Arthur Clarke himself for, like Alfred Hitchcock before him, he likes to appear 'somewhere in the film.'

"With Peter Hyams to interpret Clarke's work, perhaps we may see more of our former Chairman's creative novels committed to the big screen."

Members of the UK IRAS team with their NASA awards. NASA Administrator James Beggs in front of the US flag. *RAL*



FROM THE SECRETARY'S DESK

Keeping an Eye Open

We have received a specimen M-17 elbow-type Moonwatch telescope for display, one of those formerly used by the Society as part of its programme for observing orbiting satellites.

We ran three such Moonwatch teams for a number of years from 1958 on. The first Vanguard launch, sadly, failed: even more unfortunately, news of it did not percolate to the United Kingdom for some time, with the result that the office was manned throughout the night awaiting observations of a satellite which had stayed put.

In other ways we were more successful. For example, a trial run one evening produced a satellite, well enough, but moving in the wrong direction! This puzzled us no end. It was only afterwards that we were told that it was actually a Soviet Luna probe which had circled the Moon and, unexpectedly, returned to Earth orbit once more!

We have, for some time, been trying to get an early brass telescope and an antique celestial globe for the Society. These used to be easy to come by but not any longer.

What a pity my own brass telescope on a claw stand did not survive the war. It only cost £3 then and would have looked most decorative in our Library.

Planetary Flyer

We were very glad to welcome Dr. Glen S. Orton, who flew into London for a joint ESA-JPL study on using one of the Mariner Mk. II probes for Project Cassini, and took the opportunity to visit us. Cassani is a Saturn Orbiter flight with a probe for injection into the atmosphere of Titan, its largest satellite, with Titan subsequently providing gravity-assist orbits for multiple encounters with other satellites in the System.

The study is still pre-phase A though a launch date of 1993-4 is envisaged with Saturn encounter around the year 2000.

Glen has a particular interest in remote sensing of planetary atmospheres in the infrared, which accounts for him being also on the Galileo science team. Even his graduate work at Caltech was on determining the temperature structure and hydrogen-helium ratios in Jupiter's atmosphere, using data from Pioneers 10 and 11, a process repeated once again when Pioneer 11 went on to Saturn.

Shades of Times Past

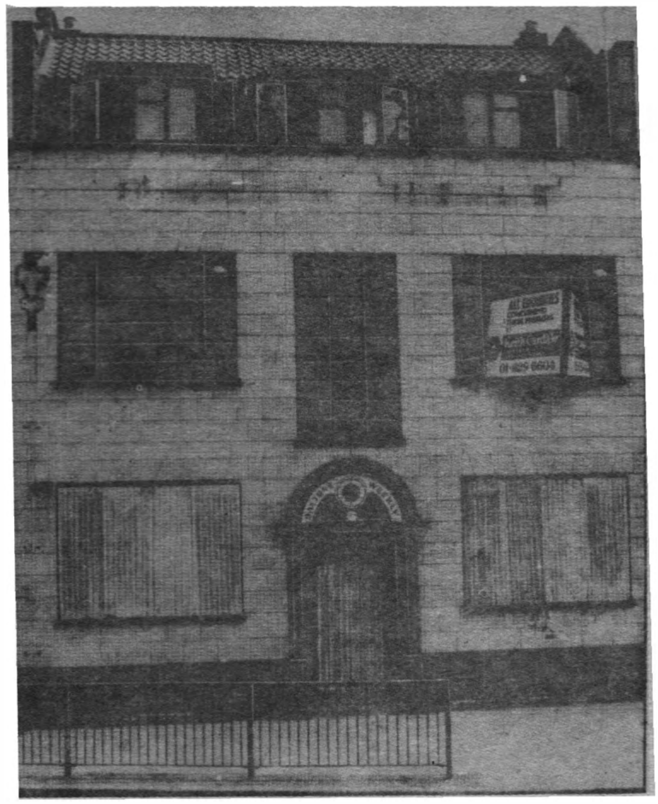
I have been trying to unearth further information about the history of our HQ, part of which was formerly the editorial offices of the magazine *Daltons Weekly*.

It transpires that the first copies of this appeared in 1865. They were printed for Mr. Dalton by James Hebert in the kitchen of his home at 21 South Lambeth Road. Hebert took over the paper when Mr. Dalton died around 1872.

Business increased and expanded to embrace houses 23 and 27 and, in the late 1950's, Nos 21, 25 and 29 were added as well. All except Nos 27/29 were subsequently demolished as part of a road widening scheme.

In 1972 *Daltons Weekly* was taken over by the Morgan-Grampian Publishing Group. At that point the earlier management ceased to have any interest in the business so Nos 27/29 remained derelict for nearly a decade. Meanwhile, the site was bought up by a speculative property developer, though trouble emerged when No. 29 was declared a Grade II listed building. Problems became even more burdensome when the property market collapsed and the "Stern empire" - which had bought the site - then collapsed too.

At that point I was sauntering past the building, saw the sale sign go up, and made initial enquiries.



Right: Sidney Herbert, printer. *Above:* 27 South Lambeth Rd., as it appeared shortly before conversion into one half of the Society's offices.

Rock of Ages

All sorts of material is submitted for publication, some in a class by itself. I have a practised eye for such things and thus easily spotted a stirring text mentioning "a rising class of dynamic, aggressive profesionals." These, it continued, were "a breed apart from their fellows," though I was sorry to see that "they lack a symbol to distinguish them from their declining predecessors." The main text, about selling Moon rock at $3 per gram for incorporation in pencil-holders, key-rings and similar

knick-knacks as fund-raising exercises at planetaria, observatories and the like, seemed relatively unimportant.

I was anxious to find the passage showing that I, too, was one of the "breed apart," feeling sure that the author would exercise decency or good taste in mentioning it, if only for tactical reasons. After all, honours are lavished on all in influential positions, illiterate or not.

Unfortunately, he didn't.

Perhaps he knew that I am seeking a Sainthood (I need only find the address and pay the money) and felt he shouldn't compete.

Sound Advice or Bad News?

I usually run for cover when asked to act as technical advisor to the media. Manifold bruises bear testimony to past encounters.

It wasn't always so. Many years ago I was asked to provide technical advice on a series of space programmes. I responded with alacrity, only to discover that the text had been written by a 16 year old youth with little knowledge of space but commendable knowledge of TV effects - the latter endearing him to the Producer. After only one meeting it became clear that the "technical advice" was to be purely nominal. Unfortunately, having just degutted all the scripts, I was ill-prepared for this.

Fortunately, the result was painless. I collected the cash and went. What happened to the scripts and the 16 year old protegé I have no idea but I still regard the whole episode with warm affection.

After all, I got paid. That wasn't always so, either.

Legal Beagles

We had to see our Solicitors the other day about tying up the legal side of our proposed extension plans.

It brought to mind how they first came to represent us. It began over thirty years ago with an offer of help from Owen Howell, a keen member of the Society and Senior Partner in the firm of Neish, Howell and Haldane. He dealt with all our affairs as a labour of love and, on retirement, donated us to his successors rather in the manner of a legacy.

His practice is now part of Macfarlanes, one of the leading legal firms in the UK.

The Sky's the Limit

We've done rather well with proposals of late, all bigger and better than any before. Things began, modestly enough, with a request to provide a scientific programme of experiments for a group about to watch an annular eclipse of the Sun. From then on it rapidly expanded into a major campaign to promote space by influencing ITV, BBC and all the mass-media. Admittedly the idea was linked to the UK but it was a clear case of "tomorrow the world." Almost immediately afterwards was a request for "the Society" to provide a Development Brief. This was to cover the design, supervision and construction of spacecraft and related items to employ 1800 people. The time limit allowed was three full days, from which had to be deducted the two days it took for the letter to reach us.

A nice touch came with the proposal to send a booklet promoting space to every household in the UK, some 26 million or so. To show goodwill the writer of the letter kindly offered to prepare the booklet himself. I thought this the least of our troubles. If only he had offered to pay for producing and delivering it.

I have revised my requirements since my last note. A small army will no longer suffice. Instead of a few squads or a battalion or two, I now need whole divisions.

Plane Speaking

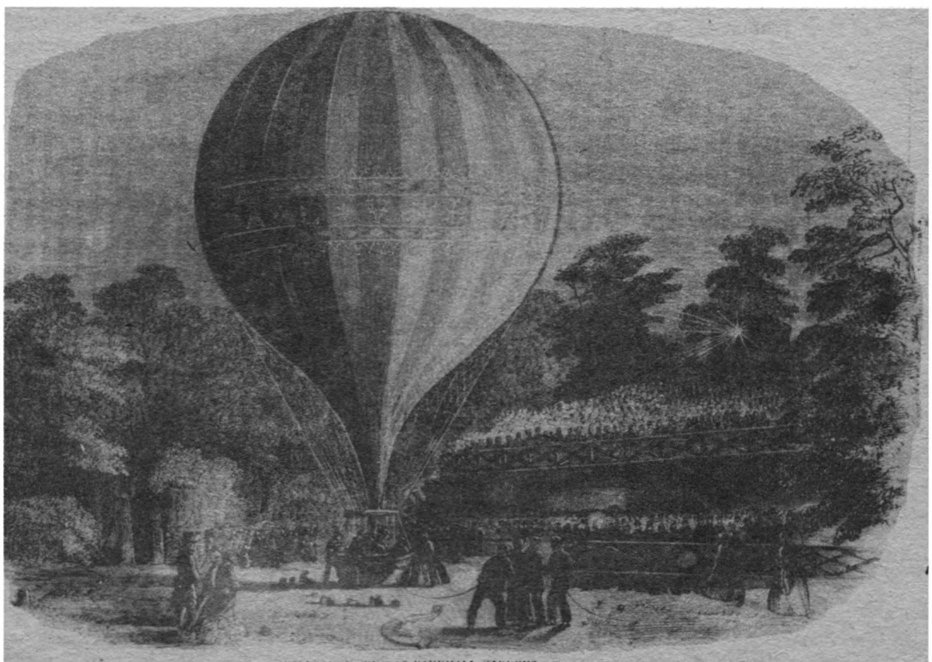
For many years our Society was inextricably mixed, in the minds of the popular press at any rate, with the Flat Earth Society whose main argument, as I recall, was that since rivers do not flow uphill yet some flowed North, East, South and West, the Earth must therefore be completely flat. This, no doubt, accounted for confusion on the part of the popular press who were thereby led to imagine that space travel consisted simply of falling off the edge of an otherwise flat Earth.

A similar good cause, which I commend very highly, is the "Save Gravity" campaign. I was happy to note from "Campus Life" that tongue-in-cheek "American Society for the Conservation of Gravity (ASGG)" has been organised to oppose all plane and space flights because they are rapidly depleting one of the world's most vital resources. "A single Moon rocket launching uses more gravity in a few moments than the entire

Up, Up and Away

We were happy to acquire recently a handbill and display bill advertising balloon ascents from the once-renowned Vauxhall Gardens, dated 1849. At that time balloon ascents were great events, attracting spectators from far and wide.

It is interesting to realise that such daredevil pioneering once took place only a stone's throw from the Society's present offices.



BALLOON ASCENT AT VAUXHALL GARDENS, 1849.

world used during the 18th century." The United States, with only 6% of the world's population , now uses 69% of its gravity. Current projects include research on synthetic and artificial gravity and a proposed petition to the American President, which I applaud, asking that the ton be reduced to 500 lb.

It will be a relief to have the weight on my shoulders reduced by 50%.

A Catch in it

I like catch phrases with a space slant, e.g. the correspondent who heads his letter paper with "Space is the Place." I thought the sign outside the old Hawker Siddeley entrance reading "Cars parked in space at owner's risk" was a most worthy offer, if only to rid us of the cars double-parked near our offices and preventing access to our side entrance.

Another, profound in its significance, is "Are you in the right place?" I sometimes doubt if I'm in the right *world,* let alone the right place.

Even more arresting was one that came the other day. It was a beautiful brochure headed "The ultimate meeting space."

It was an invitation to hold Society meetings in Singapore.

Bermuda Try-Wangle

I felt well-disposed to a recent letter addressed to *every* member of the Society, congratulating them on having *formulated highly-developed inner resources and a higher order of perception and intelligence that is in order with the Cosmos,* though not completely happy to include the person still addressing me as "Hallo Cock!" and who, self-evidently, fails in perception. Others, too, may fall by the wayside for the letter goes on to introduce the requirements of *purity* and *perfection,* both of which could thin out the ranks a lot.

Perhaps the writer was not altogether pure, himself, for he rattles on about the need to "set up a small, highly simplified communications sytem in Bermuda," including the purchase of a small island.

Doubtless, members with highly-developed inner resources, as well as being pure and perfect, will be expected to have highly developed cash resources too. I can manage the first but am doubtful about the last two.

Cigarette Cards

The article on cigarette cards held in the Society's collection provoked an interesting response in the shape of a request from *Cigarette Card News* to provide a short article on the space cards which I prepared for Anglo Confectionery some twenty years ago.

It would be good publicity for the Society though, truth to tell, I have no idea what to write. It's not easy to remember twenty years ago when fully-stretched memorizing the commitments of today.

Healing Balm

Even if involuntarily, I must be a psychologist of no mean order.

My main balm is to be the recipient of curious letters. Three, recently, consisted of nothing more than 'Sir' and 'Sincerely.' Another 30-odd urged me to look up an obscure 1964 encyclopedia reference, and I enjoyed one suggesting that a lunar crater be filled with sea water. The writer was vague on his reasons and technical details but specific about who was to go to Vienna to get the project under way! Best of all was one asking my help to get a large corporation to invest $50 billion, out of which the writer was to get 1%.

I treated with distrust, however, the letter which began 'I... being of sound mind and possessing profound inventive and prognosticative capabilities.'

I hate rivals.

Crank Case

Musing over a phone call the other day ('I've evidence of life on Mars but my papers were destroyed before the war') brought to mind the fact that no-one has ever said 'I'm a crank.' They invariably begin 'I'm *not* a crank!'

Interestingly enough, about 90% of those 'not a crank' insist on extreme secrecy e.g. 'I must see you *personally!'* They also display marked reluctance to reveal, beforehand, what they want to discuss.

Cooped Up

I was saddened to read a piece about Blue Streak in the *Daily Mail* of 28 November to the effect that 'the gleaming rocket designed to take Britain towards the stars has found a new role - as a chicken coop in the South American jungle.'

The article went on to say that 'it was sold for a few thousand pounds and towed 30 miles into the Jungle.'

That must make it one of the most expensive chicken coops in history. Even worse, it reopened an old wound of long ago. This concerned a tramcar once used as a Director's Dining Car. This, also, ended up as a chicken coop.

Attractive Models Wanted

Readers will, no doubt, have noted from the pictures in previous issues of *Spaceflight* that a range of attractive space models adorn the tops of the Library bookstacks and provide a very nice "atmosphere." They are mainly of rocket and satellites though we would like to see globes of the Moon, Mercury and Mars and some astronomical models also, if they can be found. Reg Turnill produced four spacecraft models at our 50th Anniversary Celebration dinner last: another, a model of the Giotto spacecraft, came by courtesy of British Aerospace, and Dave Shapland presented one of Spacelab just recently.

A visit to Estec brought to light the interesting fact that the range of models of this order (scale about 1/40) is even more extensive than we had imagined so scope for extending our collection might still exist. A quick calculation shows that we have space for another 20 models. (We are not seeking the plastic "kit" models but those prepared by and for various aerospace companies and organisations.)

It would be nice to see our collection enhanced and Library users too, no doubt, will be pleased with an enlarged decor.

Glued to the Launch Pad

A report in the *Observer* magazine recently caused some concern. Headed "Permanent Boots" it went on to say that, over a long period, boot leather could be fused to the skin of a foot and thus become a single tissue. This, it explained, was why many cowboys had to be buried with their boots on.

Having occupied the Executive Secretary's seat for almost 40 years now, one can see the cause of my anxiety. Was this the original concept of fusion reaction? Were my nether regions at risk? Had I become hidebound?

Fortunately, reverential exploration showed that all was well. It was a salutary lesson just the same.

BOOK NOTICES

Astronomical Cuneiform Texts
Ed. O. Neugebauer, Springer-Verglag, Heidelberger Platz 3, Postfach, D-1000 Berlin 33, Germany, Vols I and II 511pp, Vol III 255pp, 1984, DM 268.

This is, clearly, a labour of love. Volume I is concerned with Babylonian Ephemerides of the Seleucid Period, for the motions of the Sun, Moon and planets. When first published in 1955 this work described all the fragments that the author could then examine, since augmented now by the many more fragments identified over the past 25 years. The material presented in its entirety now concerns about 300 tablets and fragments i.e. about four to five times as much as was previously known. About 170 tablets relate to positions of the Moon; the rest have to do with the planets, with Jupiter better represented than all the others combined.

Most of the tablets have been written very neatly in carefully arranged columns and lines, probably as 'final copies' made from preliminary manuscripts. Many begin with an invocation and end with colophon which gives the owner, scribe and date of the tablet. About one third of all tablets come from Uruk: the remaining two thirds, probably, from Babylon.

The motion of the Moon was particularly important in ancient Mesopotamia because the civil calendar was based on a lunar calendar, with the beginning of each month determined by the first visibility of the new crescent. The accurate prediction of this event was the main goal of Babylonian lunar theory. The methods used and results achieved greatly influenced all further progress in ancient astronomy though the history of Babylonian lunar theory, itself, is unknown. Almost the whole body of available evidence consists of the tablets published here, though these show only the application of a fully developed theory for the calculation of ephemerides. Calculations of this type also made possible the prediction of solar and lunar eclipses, though only in general terms.

While Vol I was concerned almost solely with the motions of the Moon, Vol II considers the planets though the total number of surviving texts for all five planets together is less than half of the lunar text, and in a state of preservation worse than for the lunar records. There was a fundamental difference between Ptolemy's theory of the planets and the Babylonian theory, as currently known, for whereas Ptolemy's goal, in modern terms, related to the positions of planets on a daily basis, the Babylonians regarded this as of secondary importance. They were more concerned with risings and settings and with oppositions, etc. Once these were known, they determined the location of planets for intermediate times by means of complicated interpolations.

Volume III consists wholly of plates. Practically all of these consist of tabular data giving the content of each tablet examined and include a number of drawings (and photographs in some cases) of many of the items described. It is this latter which show most clearly the monumental nature of the work undertaken to make available, in modern form, these records from antiquity.

Zwischen den Planeten
(Between the Planets: Comets, Asteroids and Meteors)
H-M, Hahn, Franchkh-Kosmos, Postfach 640, D-7000 Stuttgart 1, Germany, 207pp, 1984, DM 24.

This is a very interesting pocket-type book, in German, excellently produced in good time to meet the increasing interest stemming both from the Halley's comet probes and the planned asteroid fly-bys. Halley's comet, itself, features prominently in the book, the discovery photograph and its 1985/6 celestial path being included. Actually, the cometary aspect predominates with more than half the text given over to these bodies, the remainder more or less being evenly divided between the other two topics.

The book is very readable yet its information content is high, with the result that it should interest a wide range of readers.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

SOCIETY SPECIAL COLLECTIONS

The Library Committee greatly appreciates help from both Members of the Society and its many friends in carrying on its work. Part of this includes building special collections for display in the Society's Library and for its Archives, for the Society recognises its obligations not only to provide current data but to preserve and record a selection of material for posterity.

To meet the wishes of those who want to help but who need further information the Committee has compiled the following list of its special current interests and which indicate only too well the wide-ranging scope of its ambitions.

SPECIAL COLLECTIONS

Slides: 35 mm (2 in.) On all space topics and astronomy both current and historical, leading personalities active in these fields.

Historical Books: These are usually volumes over 80 years old which were concerned in promoting interest in the Heavens. They include star maps and atlases, biographies, pamphlets on astronomical or space-related discoveries, etc.

First-day Covers: Relating to both astronomy and space and of any vintage.

Halley's Comet: Books, pamphlets, souvenirs or any material relating either to the 1985-6 appearances of Halley's comet or any of its earlier returns.

Eclipses of the Sun: Pamphlets and books concerned with recording expeditions to witness eclipses of the Sun.

International Astronautical Federation: Photoraphs and souvenirs relating to its annual congresses.

Photographs: Black and white photographs of any vintage on any space or astronomical topic or of leading personalities associated with this work.

Coins and Medallions: Relating to astronomy and space, of any vintage.

Models: The Society's Library has a collection of scale models of spacecraft (not kits) which it would like to see augmented.

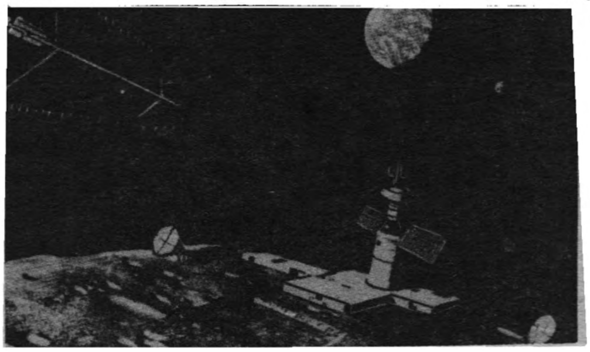
Reports and Documents: We are particularly interested in obtaining copies of reports and documents, of any vintage, relating to space projects, particularly those items which did not receive wide distribution.

Science Fiction: Works of particular significance issued before 1914.

Personal Correspondence: Letters and similar personal items signed or formerly owned by leading figures in astronomy and space.

Comets: Books, pamphlets, articles, drawings and photographs relating to any comet.

Astronomical Telescope and Celestial Globe: We do not expect much under this heading but even one of each would be appreciated.

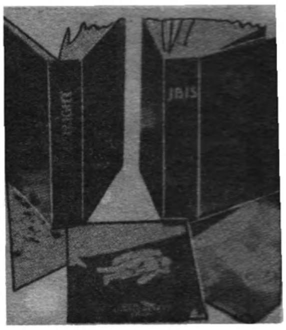


The first of this year's *Space Education* issues includes a range of articles on astronautics and astronomy. Two cover infrared and X-ray astronomy from above the atmosphere, emphasising the enormous strides achieved since the beginning of the Space Age. The Voyager encounter with Neptune in August 1989, which will revolutionise our knowledge about the planet, is reviewed in a NASA/JPL article. Robert Frisbee contributes the first part of a comprehensive basic survey of rocket propulsion systems while Robert Mackenzie completes his description of an exciting branch of astronomy with 'Meteor Astronomy: Comets, Minor Planets and Meteor Streams.'

Tom Patrick, of the Mullard Space Science Laboratory, provides an insight into the structural design of satellites, and Robert Christy, who contributes the regular 'Satellite Digest' to *Spaceflight*, considers the geostationary orbit in 'An Orbital Guide.' Roger Smith discusses the use of Landsat imagery in the teaching of geography and Paul Maley describes how to employ video techniques in amateur astronomy.

Copies of the May *Space Education* can be ordered for just £2 ($4) each, post free.

BINDERS



The ideal way of keeping your magazines in perfect condition. *Spaceflight* binders carry *BLUE* covers, those for *JBIS* are *GREEN.* Gold lettering on the spine identifies the magazine, volume number and year. Cost: £5 ($8 abroad) each. Note: *JBIS* binders fit post-1976 volumes.

SURPLUS LIBRARY BOOKS

We have a number of surplus Library Books and Reports on astronomy and space that are being offered at very low prices. To secure a list of those available, simply send a reply-paid envelope with your request to The British Interplanetary Society, 27/29 South Lambeth Rd, London SW8 1SZ. If you spend £20 or more you may deduct a 10% discount.

Please enclose a 20p stamp and specify if you require the Book List, Technical Report List, or both.

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices, please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Answers to "Test Your Space Knowledge"

1. Alan Shepard.
2. Mariner 10.
3. Explorer 1.
4. Sputnik 2.
5. All have flown in space on more than one occasion.
6. Phobos and Deimos.
7. Apollo 15 crew.
8. Launch failure. Crashed into Atlantic Ocean.
9. Intelsat 1 communications satellite.
10. The proposed class of NASA/JPL planetary orbiters modified from Earth satellites, e.g. Tiros.
11. Titan III-Centaur E.
12. Jupiter.
13. A corned beef sandwich.
14. Viking 1 (Mars, 1976).
15. LAGEOS.
16. Luna 17.
17. France.
18. Venus
19. Anita and Arabella.
20. Mariner 2.
21. Radio 'hams'.
22. Weather information.
23. 1961.
24. 1986.
25. 15. Three in Apollo 11 and 12 in STS-1 to 5.
26. Voyagers 1 and 2.
27. Viking.
28. Vladimir Komarov.
29. London.
30. Titan.
31. Gemini 5.
32. 1988.
33. The Sun (Solar Maximum Satellite).
34. Venus 9 in 1975.
35. Shuttle PAllet Satellite.
36. Mercury.
37. 1972.
38. ISEE-3 with comet Giacobini-Zinner.
39. A Soviet Space Shuttle test flight. Recovery in the Indian Ocean was photographed by Australian aircraft.
40. Search for Extraterrestrial Intelligence.
41. French Guiana.
42. Uranus.
43. Russell Schweickart.
44. Bob Parkinson.
45. Lightning. (Night/Day optical survey of lighting).
46. Nuclear-powered satellite which crashed in Canada's NW Territories.
47. Discoverer 1, 1959.
48. Earth Resouces Technology Satellite 1.
49. It was a handcart used to transport equipment and samples on the Moon.
50. Arnaldo Tamayo Mendez.
51. Ships used to recover Space Shuttle boosters after launch.
52. Boeing.
53. A huge array of antennae which would search for signals of extraterrestrial origin.
54. Norman Thagard.
55. N. Armstrong, E. Aldrin, M. Collins and R. Nixon.
56. Apollo 12.
57. *Challenger*
58. Japan.
59. Manned Orbiting Laboratory.
60. Apollo 8.
61. John Young in Apollo 10.
62. 9 February 1986.
63. 4: Giotto, Planet A, 2 Vega.
64. Guion Bluford (STS-8).
65. Valentina Tereshkova, Svetlana Savitskaya, Sally Ride.
66. The Soyuz rendezvous radar failed to deploy and the mission was aborted after a mannual approach attempt was called off.
67. Luna 2, September 1959.
68. Vega.
69. IRAS (Infrared Astronomical Satellite).
70. It is the common name for the Star β Centaurus.

Pictures

1. The 1960's Orion nuclear pulse rocket.
2. The Cyclops SETI proposal, mentioned in ques. 53.
3. ESA's Infrared Space Observatory, approved as the next science project.
4. The Pioneer 10 Jupiter/Saturn probe.
5. The Manned Manoeuvering Unit for Shuttle astronauts.

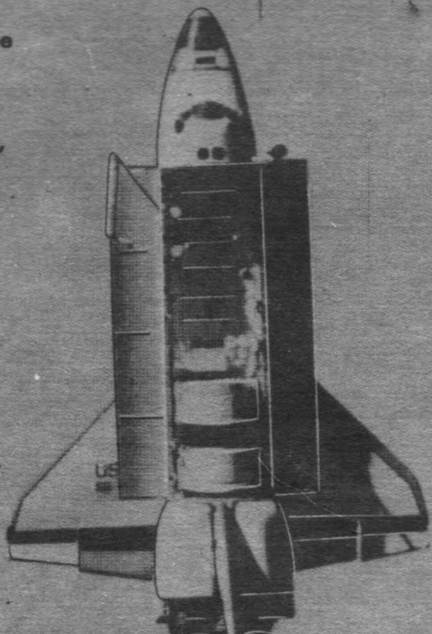
SOCIETY BOOKS

PROJECT DAEDALUS

The publication of the Project Daedalus Final Report marked the end of years of painstaking work by a group of BIS pioneers. The BIS received congratulations from around the world for its far-sighted project: designing a probe for man's first crossing of interstellar space.

The Final Report Report contains 24 papers spread over 192 large-format (A4) pages, summarising the four year study. The papers cover the overall spacecraft design, mission profile, computer systems, navigation, experiments and our knowledge of nearby stellar systems, some of them possibly with planets.

"Daedalus" is acknowledged as a milestone in the the development of advanced astronautics. Copies of the Report cost just £7.00 ($11.00) post free.



THE EAGLE HAS WINGS

An exciting progression of space achievements in the years following the Second World War led to Man's first landing on the Moon in 1969. Rockets for probing the upper atmosphere evolved into the space launchers we know today. Vanguard, Explorer, Atlas, Titan, Mercury, Gemini, Apollo – a succession of names to conjure up memories of the 50's and 60's when man was taking his first tentative steps into outer space.

The Eagle Has Wings tells the story of the major US Space projects from 1945 to the watershed year of 1975, when the Apollo missions came to an end and the first wave of interplanetary exploration gave way to the more sophisticated probes of today. Written by *Spaceflight* managing editor Andrew Wilson, it is packed with information and photographs. It runs to no less than 144 large-format pages and can be obtained for the low price of £7 ($11.00) post free.

HIGH ROAD TO THE MOON

Every member ought to own a copy of this unique 120 page publication which records many of the Society's early ideas and discussions on Lunar exploration in the visionary drawings and illustrations of the late R. A. Smith.

Pictures and drawings detail plans for orbital rockets, space probes and ships to take men to the Moon and Lunar exploration. Some are familiar illustrations used in books of the time: others have not been published before.

Bob Parkinson has brought these pictures together with a commentary which tells how the pioneers imagined things would be and how they actually were. It goes beyond the present, for man's involvement with the Moon is not yet finished. Using the Smith pictures as a background, Dr. Parkinson looks at the possible future for the Moon and how it might be brought about.

Price: £6.00 ($9 .00) post free.

THE BRITISH INTERPLANETARY SOCIETY

All of the books are available from: The British Interplanetary Society, 27/29 South Lambeth Rd., London SW8 1SZ, England

spaceflight

Opinions in signed articles are those of contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01–735 3160.

NOTICES OF MEETINGS

Lecture
Theme: **PLASMA PHYSICS IN SPACE**
by Dr. D.A. Bryant
Rutherford Appleton Laboratory

Results from the three-satellite AMPTE mission, launched in August 1984 to explore by revolutionary new techniques the interaction of the solar wind with the Earth's magnetosphere and the comet-like behaviour of injected plasma clouds, will be discussed.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **1 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture
Theme: **COHERENT LIGHT FROM SUPERNOVAE**
By A.T. Lawton
President of the Society

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **15 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

One-day Forum
To be held in the Society's Conference Room, 27/29 South Lambeth Rd, London, SW8 1SZ on **Saturday, 1 June 1985**, 10.00 a.m. to 5.00 p.m.

Topic: **THE SOVIET SPACE PROGRAMME**

Subjects will include :

History of the USSR Lunar Programme

Cosmonaut Update

Soviet EVA Experiments

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

Lecture
Title: **SATELLITE INSURANCE**
By R Buckland

Launching satellites into space is a risky business. No commercial project can go ahead without insurance to cover launch and other risks. This talk will describe the role that satellite insurance plays in the development of commercial activity in space.

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **12 June 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time, enclosing a stamped addressed envelope.

Lecture
Theme: **METEORITES: SURVIVORS OF THE EARLY SOLAR SYSTEM**
By Dr. A.L. Graham
Dept. of Mineralogy, British Museum

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **18 September 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:

3 Apr 1985 | 1 May 1985
15 May 1985 | 12 Jun 1985

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

ELECTIONS TO COUNCIL

The Report of the Scrutineers on the ballot papers counted up to and including 31 January 1985 was as follows:

Number of Papers received	913
Number of spoilt Papers	1

The names of the Candidates and the number of votes cast for each was as follows:

Position	Name	Number of Votes
1	G. V. Groves	802
2	R. A. Buckland	768
3	M. R. Fry	745
4	G. V. E. Thompson	592
5	J. A. Andrews	510
6	F. R. Smith	147

The four candidates receiving the highest number of votes and who were accordingly elected were:

G. V. Groves — R. A. Buckland

M. R. Fry — G. V. E. Thompson

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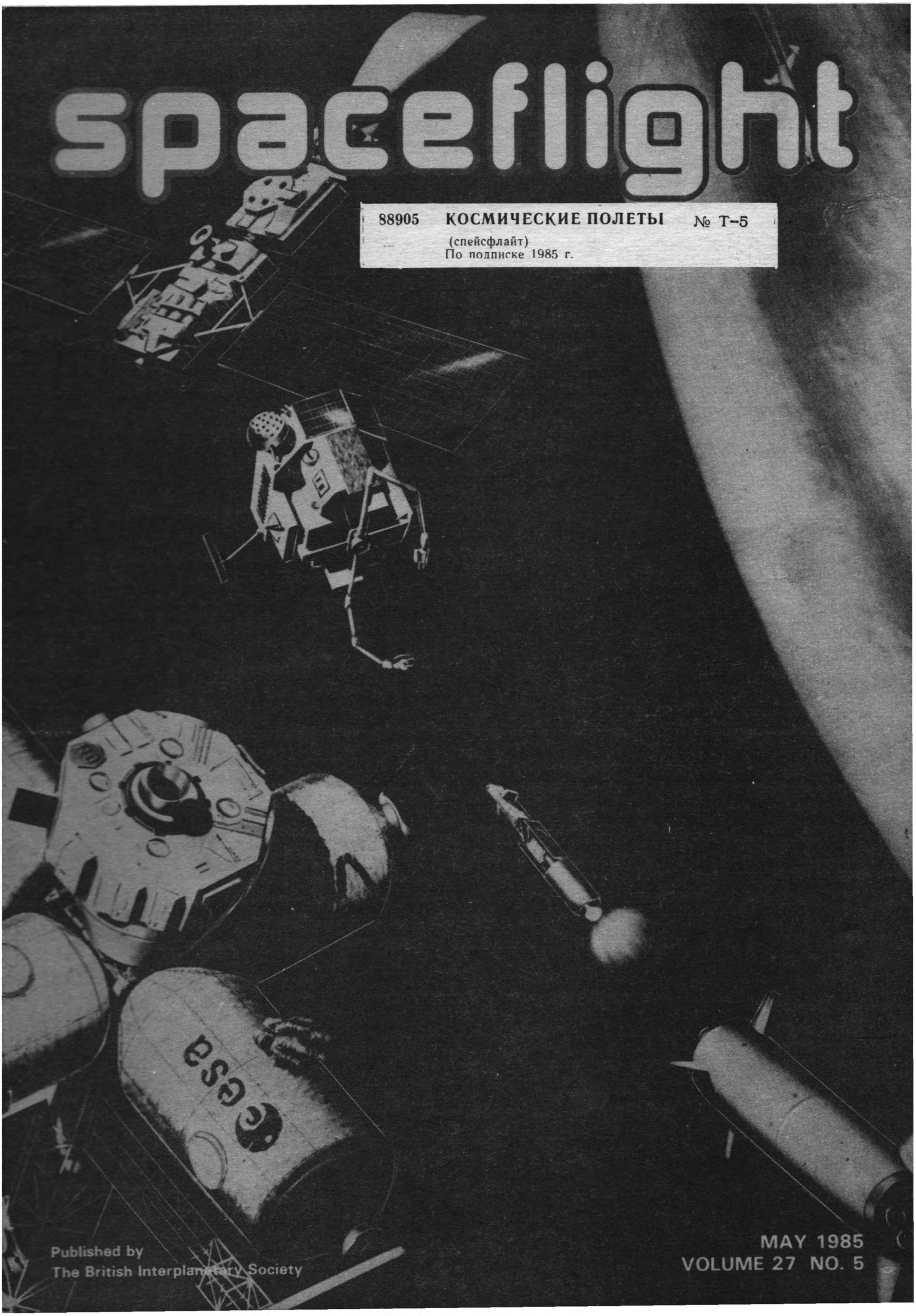
По подписке 1985 г.



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MAY 1985
VOLUME 27 NO. 5

MEET THE UK ASTRONAUTS

The first Briton to travel into space is due to go aloft in 1986 aboard the Space Shuttle with a UK Skynet communications satellite. All four of the candidates in training - Nigel Wood, Richard Farrimond, Peter Longhurst and Chris Holmes - will be Guests of Honour at a special dinner to be held at Society headquarters on the evening of Friday, 21 June 1985.

This is a unique opportunity to meet the men who will be part of space history. There are only a limited number of places available, so early application is essential. The cost (including sherry, 4-course meal and a half bottle of wine) is £18 per person.

Registration forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Top left: Nigel Wood (RAF), *top right:* Richard Farrimond (Army); *bottom left:* Peter Longhurst (RN); *bottom right:* Chris Holmes (MoD).

DELUXE CERTIFICATES

Both Fellows and Members may now purchase high-quality certificates suitable for framing. These are 29.5 x 41.5 cm in size, printed in three colours and with the member's name hand-inscribed. They are available for only £5 ($8) post free.

When ordering, please indicate membership grade and allow six weeks for delivery. Provision for ordering these certificates also appears on the 1985 subscription renewal form.

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices, please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

EXPLORING THE MAGNETOSPHERE

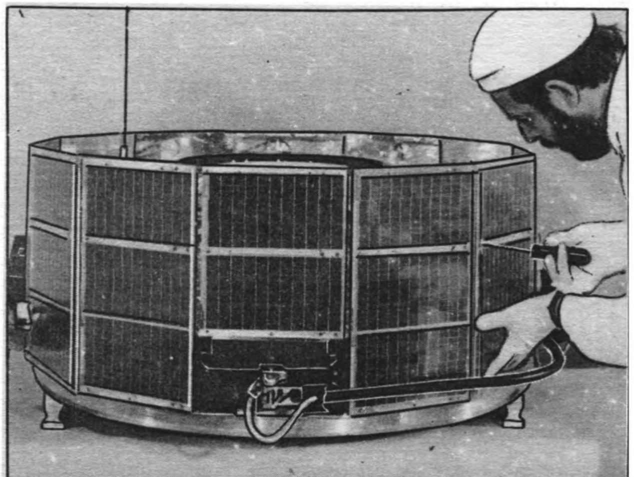
The Society has invited a Rutherford Appleton Laboratory scientist to discuss a current space experiment that is providing a wealth of new data. Dr. Duncan Bryant, the AMPTE United Kingdom Satellite Project Scientist, will describe the background to this exciting project and give an initial survey of the basic results.

AMPTE (Active Magnetosphere Particle Tracer Explorer) is a three-satellite programme launched last August and designed to explore the complex region of charged particles and magnetic fields (the magnetosphere) that envelops the Earth out to distances beyond 100,000 km. This region, as well as being of great scientific interest, protects Earth from the solar wind.

Built jointly by the Rutherford Appleton Laboratory in Oxfordshire and the Mullard Space Science Laboratory of University College London, the UKS satellite is the British contribution.

The German 'Ion Release Module' has ejected canisters of barium and lithium tracer elements for detection by UKS and the US 'Charge Composition Explorer' patrolling much nearer to Earth. Artificial aurorae and a comet have thus been created for study by scientists.

Admission to the talk at Society HQ on **1 May 1985**, 7.00-9.00 p.m. is by ticket only, available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose s.a.e.



The British UKS satellite of the AMPTE project. *RAL*

spaceflight

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Founded 1933 *Incorporated 1945*

VOL. 27 NO. 5 MAY 1985 *Published 15 April 1985*

CONTENTS

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GLOBAL MANAGEMENT

Few appear to realise that the mind-stretching, innovation, experimentation and discovery that accompany major space projects have application to problems far beyond such immediate purposes. Many of the problems facing Mankind today cannot be solved because they lie beyond our experience and capability. Space exploration will provide the key that will unlock such doors. For example, the ability to tackle the world's food problems is, really, a major task in management, distribution and economics, requiring the ability to handle large amounts of complicated data. In other words, it is a problem of logistics. As another example, the most effective implementation of the basic theories of production and distribution have yet to be ascertained, experienced and modified to meet particular situations. Yet the writing is already on the wall. Space advances have already brought Global Management one step closer e.g. with various types of remote sensing satellites. The overall task, of course, is so big that one is hard put to imagine how to tackle it. It appears to resolve itself into the problem of feeding all relevant data into a computer, big enough and speedy enough to be able to process it to produce suitable options and identify important side effects.

Space developments will, undoubtedly, play a major role in this, not only in the matter of developing and using such computers but in obtaining the appropriate data. Satellites in many fields have already indicated the importance of good data gathering, processing and communications, thus providing yet another potential feed-back into the central core of the Global Management problem.

In many ways, the Global Management problem shows basic similarities, on a more miniscule scale, to those that arise in some of the major space projects tackled today. The main difference lies in the colossal amount of data that has to be collected and fed in. That is a major task in itself. Our progress to date can probably be best illustrated by mentioning that we have just got round to finalising the Domesday book - a splendid example of data gathering in the 11th century but here, again, the input was so colossal that no one could handle it until recently!

The overall problem is not simply one demanding a technical or economic solution. There is a major political dimension, the boundaries of which would impede the implementation of any necessary decisions. In many cases it would go further by preventing even the gathering of basic data. Admittedly, the field of weather data gathering is an example to the contrary, but the constraints are real and must be recognised, nonetheless. Since

Concluded on p.240

COVER

An artist's concept of a future European orbital infrastructure. Illustrated are a launcher, an upper stage, a teleoperated vehicle, European section of the Space Station and unmanned platform with a Hermes-type shuttle attached (only the underside is visible). *ESA*

A POSITIVE FUTURE FOR ESA

By Norman Longdon

No-one attending the ESA Council meeting at Ministerial level in Rome on 30/31 January could have failed to be impressed by the optimism and buoyant atmosphere that surrounded the lively discussions. The Ministers were confident and knowledgeable as they sought to find common ground to strengthen the European Space Agency with a programme that would be of significance among the space powers of the world.

Introduction

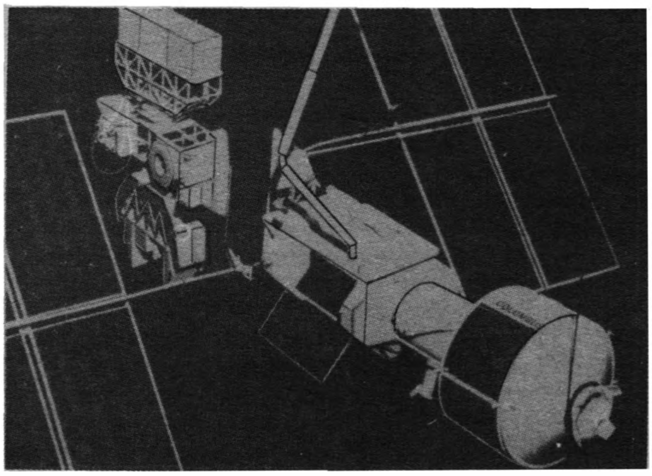
The themes were rapidly established. Europe needed a comprehensive, balanced and bold plan that would lead to autonomy in space. This would be possible only if there were a harmonious pooling of resources and ideas; cooperation was the keystone. Proof that these were not empty gestures is evident in the elements of the Resolution upon which the future programmes will be built. Such was the strength of purpose and belief in the Resolution that the Ministers decreed that it, together with a short press communiqué, should be given the widest possible dissemination: the text follows this article.

Columbus and Ariane 5

The two major new elements are Columbus and Ariane 5. Columbus will be offered as Europe's significant contribution to the international Space Station programme proposed by the US. Negotiations will shortly open with the US government, conducted against a background that includes a determination by Europe to undertake, in due time, additional elements to make Columbus a fully independent complex, including polar orbiting platforms and an operational data relay system.

Apart from continuing efforts on the Ariane 3 and 4 launchers, the Ministers decided on the development of the Ariane 5 launcher, equipped with the large HM60 cryogenic engine. This will ensure that Europe's launch capabilities remain competitive into the 21st century. At the same time, and again in support of the theme of autonomy, the Ministers invited France and her partners to keep the Agency aware of the progress of the manned Hermes programme, with a view to including it, as soon

A free-flying version of Europe's Columbus. ESA



ESA's Director General, Prof. Reimar Lüst, with Mr. G.M.V. van Ardenne, Vice Prime Minister, Minister of Economic Affairs of The Netherlands, who chaired the Council meeting. ESA

as feasible, among ESA's optional programmes. It is the present intention that Hermes should be launched by Ariane 5.

Space Science

For some time there has been stagnation in the funding of the space science programme. However, this did not deter European space scientists from putting together such a well-argued case (ESA SP-1070, *Space Science Horizon 2000*) that even those countries for which an increase in the mandatory funding of the science programme presented very grave difficulties agreed to an increase amounting to 5% a year until 1989, when the science budget will reach 162 million accounting units (MAU) equivalent, at 1984 economic conditions, to US$132 million. ESA's Member States thus recognised the considerable importance of space science as a core activity of the Agency.

The advent of new scientific disciplines in space is recognised by the wish that the Director General should study ways of including them in the mandatory scientific programme without reducing the effort in the traditional space sciences.

As the Ministers urged a vigorous continuation of activities in the fields of Earth observation, space telecommunications and microgravity, it is evident that ESA has been presented with a challenging programme.

In putting this programme into operation, Ministers realised that the Director General had inherited an imbalance in the geographical distribution of contracts and industrial return. Understandably, nations wish to take part in the technological advances that accompany such a wide-ranging programme and they expect a commensurate return on the money they allocate to ESA.

The Director General will therefore be placing considerable emphasis on the need to redress this balance as the programmes take shape. Tied in with this will be a study of the industrial structures needed to ensure that Europe has the means to fulfil the programmes *and* be able to compete in world markets. Over the past 20 years ESA and European industry have learned a great deal and must now judge correctly the industrial format, including the extent of specialisation, that will give a healthy, sharp look to the management of complex programmes.

The political will was demonstrated in Rome; now ESA and Europe's scientists, technologists and industry must show the world that a new dynamic, cooperative spirit can turn that will into exciting results.

Stop/Go

Sir, A major problem facing all Western governments lies in the stop-go nature of their activities caused, basically, by the fact that they are elected for relatively short periods, averaging five year terms. The affect of this is that major projects which cannot be accomplished easily with this period, particularly those relating to space which have a long gestation time, lie at the mercy of succeeding governments which do not take the same view as to the amount and direction of expenditure nor the order of priorities. Since every Minister is keen on showing economies of administration, the effect has been that projects initiated by his predecessors are axed and others substituted. The end result is a high level of wasteful expenditure all below any level of achievement.

The position is different in the USSR where, although leading figures may change, basic space activity is unchecked. The result is that the Soviet space programme has developed logically and continuously over many decades. Contrast this e.g. with Black Arrow project in the UK, which was cancelled at the very moment of success.

Typically, large space ventures require a gestation time of 10-15 years or more i.e. the lifetimes of three normal governments. Not only must planning take place but development studies must follow before any real activities can even begin, let alone provide a positive return for monies spent. Large space projects are divided into various phases, all spread over many years and all, unfortunately, thereby presenting frequent dates at which they might conveniently be terminated.

At one time, it was hoped that long-term international agreements would be sacrosanct and thus provide continuity to overcome the cancellation threat. Sadly, even the best of these have gone under, cancelled unilaterally by one or more governments when need or excuse arose.

The problems which, therefore, face every major space project break down into:

1. The need for a long period of continuity.
2. Confidence of support over the whole of this time.

The ingredients for success appear:

1. A wide public realisation of the importance of space activity and determination to support it. This will require a continuing dissmination of information and other material putting forward the need for space awareness at every level *viz* technical, philosophical, economic, moral, cultural, etc.
2. A long period of governmental stability.
3. A wide spectrum of political agreement on the space programme to be accomplished.

Possibly all three may be found in one country at one time but, in the case of ESA for example, whether they will be found in all cooperating countries over identical time-sales remains to be seen.

In this situation the West suffers a considerable penalty.

P.W. GOODY
London

A UK National Space Agency

Sir, The editorial in January's *Spaceflight,* advocates a National Space Agency for the UK and points out some of the dangers inherent in running this in the same way as other Government Departments. This concern has been echoed in *Space: The Future* (issued by the union TASS), a statement by Dr. M. Rees and similar comments from elsewhere, all testifying to the emerging realisation that such an agency is needed but stressing the fact that it should have specific powers, expertise and the necessary motivation. Discussion has ranged over alternatives for its internal organisation and external relationships as well as on the qualities of the staff needed to run it.

Even if a satisfactory initial mix to satisfy all these demands is obtained, longer-term problems are bound to emerge since these are endemic in this type of organisation. To begin with, the new organisation might be open to undue influence from other Government departments, including those of more senior status such as the Ministry of Defence or the Foreign Office.

Contemplation of this, alone, will bring home the fact that the simple establishment of a UK Space Agency, even if an improvement over the existing scheme of things, may fall short of its hoped-for role. Budgetary and inter-departmental problems may be held at bay by an energetic and far-sighted Director, no doubt, but might he not spend 80% of his time doing this and only 20% of it in advancing true space purposes?

More people believe now that big is not necessarily beautiful and that a small, slimmed-down type of department would prove more effective. This would undoubtedly represent a major plus, if its complement of staff were sufficiently dedicated, motivated and capable. On the other hand, if it were to be a new Government Department insufficiently grounded in technology, the past history of such establishments shows an unnerving tendency to recruit from existing departments who, to their credit no doubt, are loath to part with their best personnel and inclined to transfer those whose services can best be dispensed with.

An alternative might be to support the proposed new department, in substantial measure, with staff seconded from industry. This, at least, would ensure that the industrial base is well represented though it presents disadvantages insofar as monolithic industrial giants are not worried about home competition whereas too many small industrial companies competing for the same slice of cake could be self-destructive.

All the above points carefully avoid others of an equally significant nature. For example:

1. What should be the status of the proposed agency? This will affect its political influence, development and the extent to which it lies under direct or indirect control of other government departments.
2. Will it be simply advisory, or how far can it go in actually initiating and implementing programmes and spending money?
3. What is to be the mechanism (there usually isn't any) for ironing out or correcting any matters similar to the above that could throw the embryonic agency off-course, whether these be major gales or simply require fine trimming of the sails?

There are, sadly, no simple solutions.

P.R. FRESHWATER

The Editor is always interested in receiving items of correspondence, notes, comments, or reviews for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.

Soviet Launch Vehicles

Sir, Like Professor Ruppe (*Spaceflight*, February 1985), I was surprised to read in *Soviet Military Power* and *Aviation Week and Space Technology* of the projected new Soviet launch vehicles.

The Soviet reply that 'no decision has been reached' regarding the use of liquid hydrogen/liquid oxygen as propellants could be correct e.g. if they were pursuing a cryogenic alternative, *viz* of liquid oxygen and liquid methane. The latter material has density and boiling points akin to liquid oxygen and quite different from that of liquid hydrogen. The calorific value of liquid methane is about 40% higher than kerosene with the molecular density of the exhaust only slightly diluted by the presence of carbon dioxide.

Allowing for the reduced performance of liquid methane as a propellant, there are considerable systems engineering benefits to be gained. For example, fuel tank sizes are much smaller while the pumps used could be virtually identical to those used for liquid oxygen. All this would make for cheaper and easier production, an important parameter in Soviet eyes. I also suggest that an optimally engineered methane system would have the dimensions of fuel/oxydizer casings outlined in the drawings.

Since an oxygen/methane system may have ignition problems and the use of this combination could account for the disastrous launch site explosion reported for the prototype G type launch vehicle.

A.T. LAWTON
BIS

A Visit to 'Star City'

Sir, In late 1984 I had the opportunity to visit 'Star City' in the Soviet Union. It may come as a surprise that the general public are allowed in - not to the Cosmonaut Training Centre, but to the best space museum I have ever seen.

Star City is about 40 km northeast of Moscow and was originally two buildings used for training the first cosmonauts in 1960. The Soyuz/Salyut ground control is not at Star City nor at the Cosmodrome but close to Moscow. A film crew was recently given access to it to record scenes for a film called *Return from Space*, a fictional drama based on Soyuz-Salyut flights.

I was introduced to Lt. Gen. Georgi Beregovoi, the commander of the centre. The reason for establishing Star City was two-fold, he said. Firstly, to have 'under one roof' everything that was needed to train cosmonauts ('aircraft, centrifuge, hydrolab, simulators, equipment') and secondly, to have a community in which the cosmonauts, engineers, scientists and doctors could live. (Many workers commute into Star City in cars with special numberplates). Star City was born, he said, on 11 January 1960 when the first cosmonauts began training with the minimum of facilities: a rotating chair, a swing that spins 360° and a medical laboratory. Beregovoi recalled vividly his experience on the machines and his selection as a cosmonaut. Putting selection and training into perspective, he said that, out of 100 people, three might turn out to be very good, 60 average and the other 37 would change profession.

I asked Beregovoi how long before a flight the cosmonauts got to Baikonur. He told me that the crew leave for the cosmodrome 21 days before a flight and are exposed to a minimum of contact with other people and do light simulator work, study documents, schedules and exercise. They do not fly at all. They stay in the Cosmonauts' Hotel, which is equipped with medical facilities. Just before their flight, the prime crew and their

Lt. Gel. Beregovoi. *T. Furniss*

back-ups plant a tree in a special park. After the mission, the crew does not immediately fly to Star City but remain at the Cosmodrome for about 15 days.

I was shown the huge hanger-like building housing a replica of Salyut 7, without the new panels assembled by the latest crews. Also there is the Soyuz 2 descent module; the one-sided heating effect is particularly evident and on close inspection the heatshield looks like layers of cork with resin between them. Inside the Salyut simulator some cosmonauts were apparently rehearsing the first day of their mission aboard.

Also in the hanger were spacesuits. The EVA suit has a 'back door' comprising its life support system. The commander wears a suit with a red stripe, the engineer one with a blue stripe. The suits are custom-built, as are the moulded interiors of the Soyuz couches. I also saw the 'Chibis' negative pressure suit. Much emergency landing equipment was in evidence, including a pistol and fishing rods.

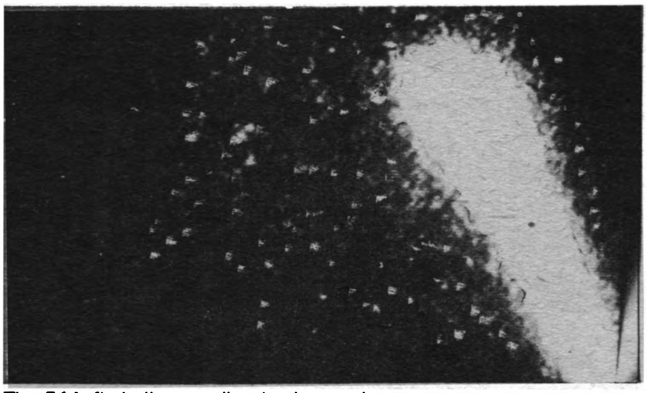
The Soyuz T simulator struck me as small and claustrophobic. The windows show moving views of the Earth and the sky and, using a small model of Salyut, cosmonauts can carry out day time and night time dockings. I was allowed an attempt and crashed into the solar panel on the left!

TIN FURNISS
Surrey

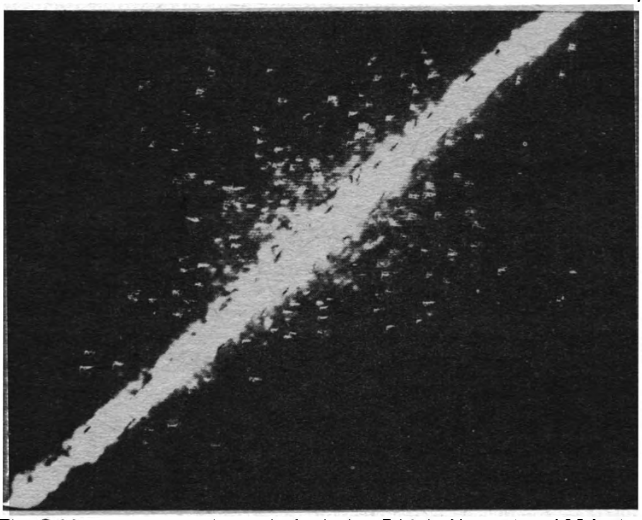
Shuttle Reentries

Sir, Texas is the only American state that is privileged to witness reentries of the Space Shuttle on its reentry flightpath into the Kennedy Space Center from 28.5° inclination flights. This is caused by the orbital configuration and the west to east trajectory that varies in latitude by the Orbiter crossrange which, in general, results in the Orbiter passing over some portion of Texas.

The NASA Johnson Space Center's favourable location relative to ground tracks allowed two spectacular pre-



The 51A fireball ascending in the northwestern sky, as viewed from Texas. *P.D. Maley*



The Orbiter reentry at the end of mission 51A in November 1984; the motion is from top right to bottom left. *P.D. Maley*

dawn reentries to be observed on mission 41B and 51A. The photographs show a highly amplified (but not magnified) view of the Orbiter reentry trail as it passed to the southwest of the Houston metropolitan area on 16 November 1984 at 11:40 GMT. In fact, there were two fireballs visible, one of which seemed to dissipate after reaching the culmination point as I saw it from LaMarque, Texas. I did not notice this on the 41B entry, which took place much farther to the south. Near the NASA area, the Orbiter is travelling at about 15 times the speed of sound about 6 km high. Even at this great range audible sonic phenomena are consistently heard on the ground. Although the visual brightness at this stage ranges from -2 to -3 magnitude, a chemiluminescent train persists for nearly two minutes. The sonic noises are similar to large fireballs and bear further study. In February 1984 I formed a small coalition of observers called the Shuttle Mobile Observers Group (SMOG). We are continuing to observe and collect data on flight characteristics as the opportunities arise.

I have used low light level TV techniques to record the passage of the Shuttle and many other Earth-orbiting spacecraft. Although the resolution is very low, it is still an interesting and useful way to make observations.

PAUL MALEY
Johnson Space Center
Astronomical Society
Houston, Texas

What's in a Name?

Sir, Apropos the item in 'From the Secretary's Desk' (*Spaceflight*, **26**, Jul-Aug 1984, p.333), our founders are to be congratulated on their choice of name for our Society (even if it was conceived on the grounds of conservatism and the fact that the technology of interstellar travel was quite unknown then) and for resisting all subsequent arguments for change.

Indeed, as Arthur C. Clarke pointed out, our initials 'BIS' can refer equally to the British *Interstellar* Society, when the need for change arises. That day may not be so far off. The confirmed discovery of the first of a new class of star, the Brown Dwarf, which is either a peculiar hybrid of super-planet or a mini-star, makes the eventual discovery of extra-solar planetary systems merely a matter of time. The discovery of such extra-solar planets will extend the literal meaning of our title by several tens of light years - distances negotiable by Daedalus-type vehicles.

In 1610, Galileo saw the satellites of Jupiter as tiny points of light. Less than 400 years later we see them as solid bodies of ice and rock. The first extra-solar planet will soon appear as a tiny point of light also. Who can doubt that, in less than another 400 years, our descendants (by remote data transmission if by no other means) will see them for what they really are.

The Society has, implicitly, long-recognised this. Its first contribution to interstellar studies appeared in a *JBIS* paper by Dr. L.R. Shepherd as long ago as the 1950's. Since then nearly 50 red-cover issues of *JBIS* devoted wholly to this topic have appeared and already constitute an invaluable source of reference to the subject.

R. SWEETMAN
London

It ought to be pointed out that the title British Interplanetary *Society does not specify that the planets involved are simply those moving around our own Sun! - Ed.*

Eclipses of 1985

Sir, Could you tell me what eclipses of the Sun and Moon will take place this year?

H. LARBEY
Manchester

Reply:

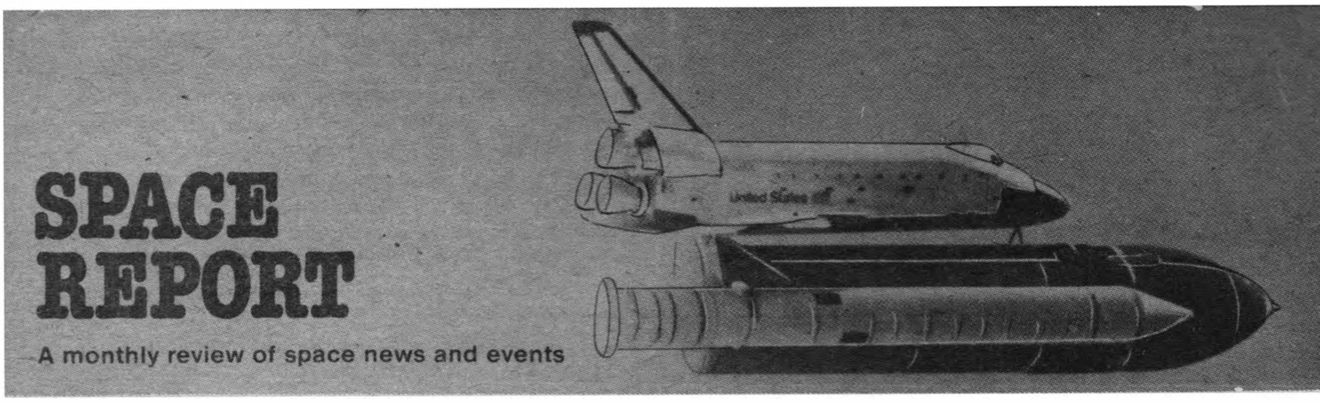
There are four eclipses in 1985 - two of the Moon and two of the Sun. The first is a total eclipse of the Moon on 4 May visible from Britain, when the Full Moon enters part of the shadow cast by the Earth as the latter orbits the Sun (by definition, lunar eclipses take place when the Moon is full; solar when it is new). A partial solar eclipse occurs 15 days later, visible from nothern North America, Greenland and Iceland, but not Britain. Another total lunar eclipse occurs on 28 October, visible from Britain. The Sun will be totally eclipsed on 12 November but it will be visible only in the far south Pacific and Antarctica (totality lasts for almost two minutes).

SNIPPET

Uranometria

Sir, I was fascinated by the account in the March *Spaceflight* of the Society's copy of Bayer's *Uranometria*. It is, of course, a very beautiful book (I have seen a copy in St. Andrews University Library) but the additional material, by Bradley or whoever, adds enormously to its interest. The Society is to be heartily congratulated on this acquisition - and on the preservative qualities of plum, or strawberry, jam!

DR. FIONA VINCENT
Mills Observatory
Dundee



SPACE SHUTTLE

PAYLOAD ASSIST MODULE CONTRACT

The US Air Force Space Division has awarded McDonnell Douglas a $169 million contract to build 28 PAM-DII stages to launch the Navstar Global Positioning System (GPS) satellites from the Shuttle, starting in 1986. This brings to 35 the total number of firm missions for the commercially-developed new version of the Payload Assist Module.

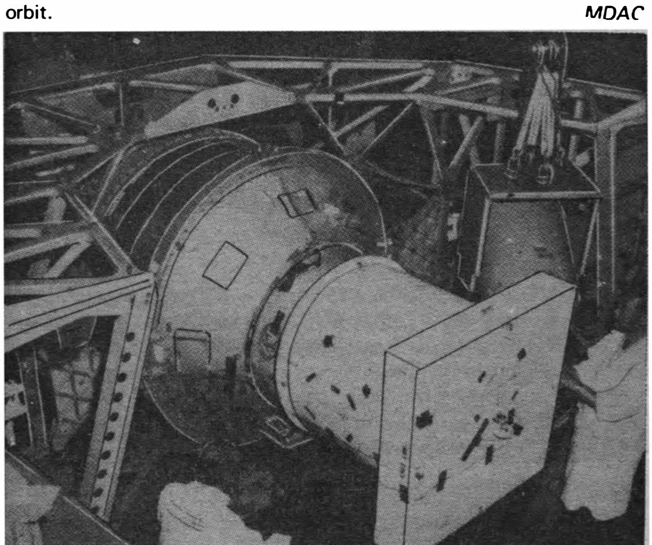
The company will begin delivery this year and continue until 1989. The first Navstar/DII flight is scheduled for 1986, although the new stage will first see use with 'Satcom Ku-2' communications satellites later this year.

Like the PAM-D, the DII consists of a single solid fuel rocket motor and the supporting structures and avionics needed to deploy the satellite from the Shuttle bay. It features a larger rocket motor that will boost the 1814 kg Navstars into 17,540 km high transfer orbits.

In addition to the motor, the system includes the reusable Airborne Support Equipment that supports and controls the stage from the launch of the Shuttle to deployment of the satellite.

When it becomes operational in the late 1980's, the unique navigation system will enable land, sea and air services to obtain instant three dimensional navigation information from any point on Earth. The network will include 18 satellites in three orbital planes. While primarily a military system, the all-weather network will also be available for civilian use. A second, coded channel will provide data to the military users.

Technicians examine a PAM-DII during tests. The pictures show a reusable U-shaped cradle that holds the system in the Shuttle, as well as the solid rocket motor (centre) to boost the satellite into a higher orbit. *MDAC*



SHUTTLE CREWS NAMED

Astronauts Francis Scobee will command Shuttle flight 51L in November when it deploys the third NASA Tracking and Data Relay Satellite (TDRS) from Orbiter *Atlantis*. It is also an opportunity to relaunch one of the communications satellites retrieved during flight 51A in November 1984. Michael Smith will be pilot and mission specialists will be Judith Resnik, Ellison Onizuka and Ronald McNair.

Scobee was pilot on 41C in April 1984; Resnik flew aboard 41D in August 1984; Onizuka on 51C, January 1985; and McNair on 41B, February 1984.

Michael Coats will command 61C in December with Orbiter *Columbia*. John Blaha will be pilot, with mission specialists Anna Fisher, Norman Thagard and Robert Springer. Coats flew on 41D and Thagard on STS-7 in June 1983. This will be Blaha's first flight. The payloads include Western Union's Westar 7 and RCA's Satcom KU-2 communications satellite, 3M Corporation's Material Sciences Laboratory 3 and the Ease/Access space manufacturing experiment.

NASA has also filled in positions on two other crews where mission specialists had been named earlier: Vance Brand, commander, and David Griggs, pilot, for 61D/Spacelab 4 in January 1986; and Jon McBride, commander, and Richard Richards, pilot, for 61E/Astro 1 in March 1986.

SSME TESTING IN 1984

During 1984, 58 test firings of the Space Shuttle Main Engines were made to give a total of 15,000 seconds of accumulated running time, writes Nicholas Steggall. A 'life extension certification' series of tests were completed on engine 2010, giving a total run time of 19,900 seconds after 65 tests, including 9,100 seconds at the 109% full power level. Information gained increased the SSME's capability to fly 20 missions before recertification testing is required. Flight acceptance testing of engines 2022 and 2023 was successful and the engines were delivered to the Kennedy Space Center. Tests continued on engine 2014 to 'green run' flight hardware to provide spares for flight engines on *Discovery* and *Challenger*. The year also included the start of Phase II development testing for high pressure oxygen and high pressure fuel turbopumps for reduced maintenance at the 109% power level.

NEW PLANETARY STUDY

NASA and the University of Arizona have signed a Memorandum of Understanding to produce a project for the detection and study of planetary systems around other stars. The agreement is to study, plan and, if approved by Congress, develop an orbiting Astrometric Telescope Facility to be mounted on the Space Station in the mid-1990's.

'Astrometric telescopes are used to measure, with extraordinary precision, the positions of stars and other celestial objects against the sky,' said Eugene Levy, Director of the University of Arizona's Lunar and Planetary Laboratory and head of its Planetary Sciences Department. Levy and David Black, head of NASA Ames' Planetary Detection Project, will be principal scientists in the collaborative project.

Black described the project as 'the beginning of a new scientific discipline. The results of the search, whether positive or negative, will profoundly alter our view of the Universe.' Until other planetary systems are found and studied, the principal project researchers say that theoretical models developed to explain the origin of our own Solar System, or the formation of stars, cannot be fully tested.

The gravitational pull of planets orbiting around a star causes the star to 'wobble' as seen against the sky. By measuring this motion, an astrometric telescope can determine the presence of planets and even some of its characteristics. The technique is commonly used by ground-based telescopes to measure the properties of double stars in orbit around each other. However, to measure the disturbance in a star's motion caused by objects as small as planets and to study the systems in detail, more precise measurements are required than can be achieved from telescopes on the ground.

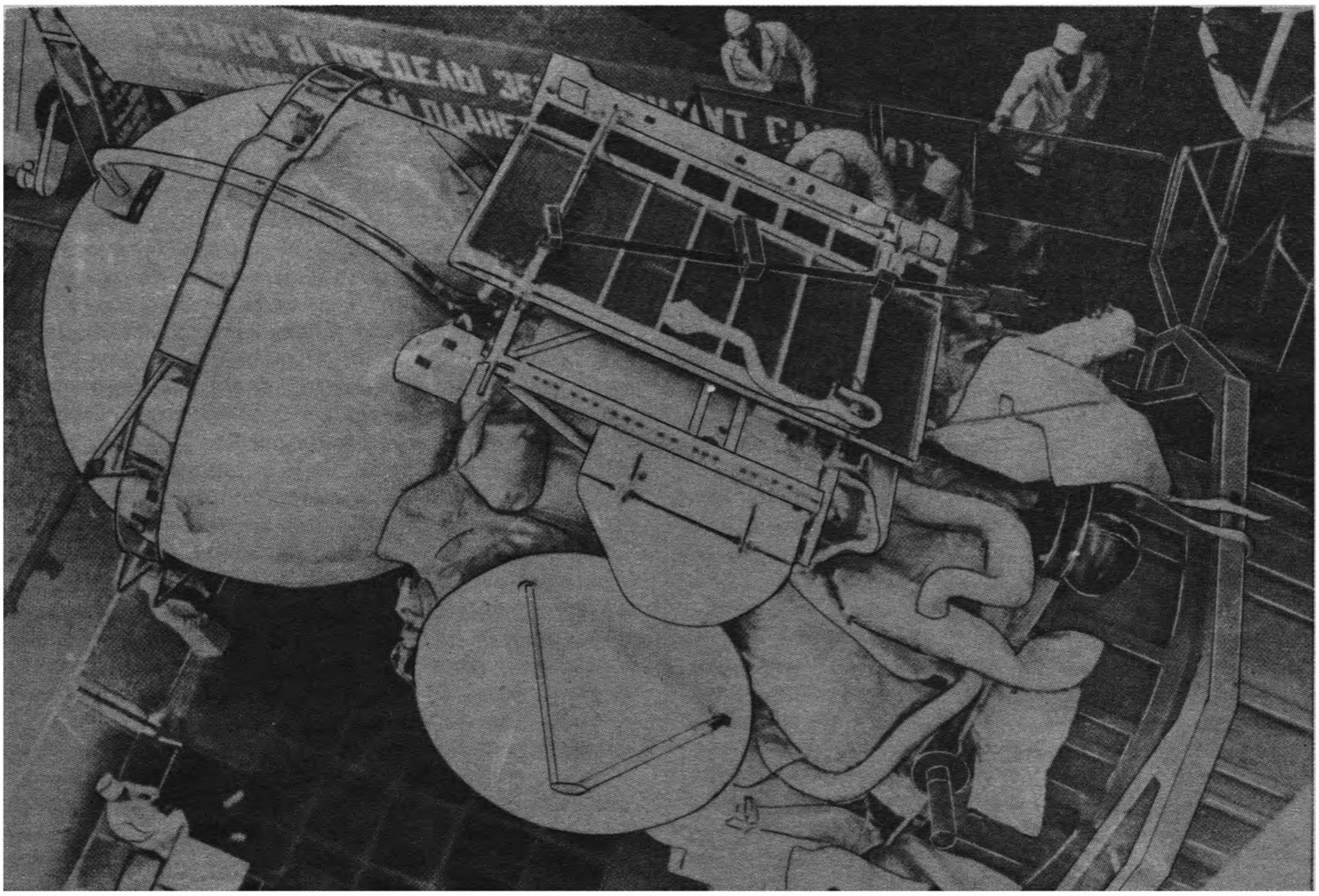
For more than a decade, Lunar and Planetary Laboratory scientists have been developing spectroscopic techniques and instruments for the discovery of other planetary systems. Although NASA and the University will work together on the entire project, Ames will coordinate the first two phases (system definition and implementation) and the University will coordinate the two final phases (the facility operation and scientific programme).

While initial study and definition work will begin soon, ultimate implementation of the project will require that NASA obtain Congressional approval and funding several years from now. Phase one will clarify the final design of the telescope and how it will be mounted on the Space Station. Phase two will build the telescope and its instrumentation as well as mount it on the Station. Phase three will establish the operating facilities on the ground. Phase four will include the scientific investigations, which will last for more than a decade. The scientists want the project to include a core programme of planet detection and study, along with a programme of guest investigations to make use of the unique capabilities of the telescope for astrometric studies of other important celestial objects.

WIDE FIELD CAMERA

The ROSAT mission, as described by Dr. John Davies at Space '84, is a German/UK mission to survey the sky at soft X-ray and extreme ultraviolet wavelengths. A consortium of British Universities is providing the ultravi-

A Soviet Vega Venus/Halley's comet probe during preparations for launch last December; it will encounter Venus in June and the comet next March. The landing craft is housed in the spheroidal capsule at left; note the communications dish at bottom and the folded solar panel. Details of the Vega project are given on pp.218-220 of this issue. *Novosti*



olet telescope, known as the Wide Field Camera. An electrical model, containing a full set of electronic components, has been assembled by the Mullard Space Science Laboratory and used to check for interference between the various subsystems. The electrical model has also been used to test the onboard computer software that will control the instrument in orbit. Full electromagnetic compatibility testing was carried out last December at Marconi Space and Defence Systems in Portsmouth.

The Structural Test Model has been assembled at Birmingham University and will be used for a series of major tests in 1985. These include a rapid depressurisation test which will simulate the sudden drop in pressure that occurs as the Shuttle climbs into orbit, and a vibration test to confirm that the Wide Field Camera can survive the shaking it receives during launch. Also planned is an extensive series of tests to ensure that the instrument can be maintained at the predicted temperature when exposed to the cold of space; correct temperature control is essential to allow it to operate satisfactorily in orbit.

Birmingham University will also be responsible for confirming that the protective door fitted across the front of the Wide Field Camera can be opened after ROSAT has been released into orbit by the Shuttle. Extensive ground testing of the door and its release mechanism will be carried out during 1985.

At the conclusion of the tests the structural model will be sent to Germany for testing in conjunction with the main ROSAT spacecraft while work in the UK concentrates on the production of the flight model.

Birmingham astronomers are also involved in preparing the mission plans for ROSAT and in the setting up of various control centres to operate the Wide Field Camera once it has been launched. After launch, members from the consortium will help to control the instrument as well as make observations and analyse the data. These data will be combined with ground-based measurements to improve understanding of the stars and of the interstellar medium.


The sterling work of British Aerospace Space and Communications Division north of London was highlighted late last November with the visit of HRH The Princess Margaret. The Princess was shown displays of the Divisions project; this picture shows BIS Fellow John Sved (right) explaining the mysteries of a spacecraft mechanism. Tony Hockridge, manager for the site, can be seen behind the Princess. Some 4000 visitors later toured the facility. *BAe*

SATELLITES

UK AMPTE SATELLITE FAILS

The UKS satellite of the Active Magnetospheric Particle Tracer Explorers (AMPTE) mission, launched last August, has developed a problem after five months of faultless operation, in which about 70% of the science data have already been obtained.

On 16 January the Operations Control Centre at the Rutherford Appleton Laboratory in Oxfordshire lost contact with the satellite, which until then had been functioning normally. Extensive checks of ground equipment and operating procedures eliminated the possibility of this problem being due to a fault at the ground station and in the following days various means, including the use of NASA's Deep Space Network, were used to try to re-establish communication with UKS.

Even so, UKS has been an oustanding scientific success, enabling scientists to add an extra dimension to the world's first studies of injections of tracer particles into the solar wind, the stream of ions and electrons that flows from the Sun. The German 'Ion Release Module' carried canisters of barium and lithium to be released at intervals for detection by UKS and the American 'Charge Composition Explorer.' Early in the mission it was decided to operate the spacecraft instruments twice as frequently as had been planned; as a result, about 70% of the original aims have been achieved. UKS was designed and built at low cost and in record time when the development of the German and American satellite were well under way.

It is too early to evaluate fully the scientific gains from the mission though there has emerged a remarkable similarity between events triggered by the particles injected into the solar wind and the phenomena created by natural obstacles in the Solar System such as magnetised and unmagnetised planets and comets.

COMMUNICATIONS

TRACKING MOVE TO WALLOPS

NASA's Goddard Space Flight Center intends to transfer all orbital satellite tracking/telemetry operations from its Greenbelt (Maryland) tracking station to the Wallops Flight Facility by early 1986. These will be combined there with the existing aeronautics and sounding rocket tracking/telemetry work. The need for ground stations has diminished with the advent of the new space-borne Tracking and Data Relay Satellites (TDRS) launched by the Shuttle.

Most of the other tracking stations in Goddard's current ground network will be phased out or transferred to NASA's Deep Space Network as the TDRS system becomes operational.

Being transferred to Wallops is work with the International Ultraviolet Explorer satellite (IUE), the Interplanetary Monitoring Platform satellite (IMP-8), the Nimbus-7 meteorological research satellite and the future Cosmic Background Explorer satellite (COBE). These satellites are not compatible with the TDRS and will continue to require ground tracking/telemetry support.

High Speed Data transfer to Goddard/Greenbelt from Wallops will be provided by a new satellite communications link. Detailed plans for the transfer are being developed and installation of antennae and equipment should start late this summer with completion in January 1986. The move should save NASA about $300,000/year.

CORONET SATELLITES

RCA Astro-Electronics will provide two high-powered Ku-band communications satellites, launch services, operator training and specialised telemetry tracking and control equipment for Luxembourg's 'Coronet' satellite system.

Each satellite will have 16 channels operating in the 14/13 GHz band using 45 W travelling wave tube amplifiers for coverage of Western Europe, the United Kingdom and the Scandinavian countries, for both receive and transmit communications service. They will also carry six spare channels for reliability.

The Coronet system will be designed for video distribution of pay-TV and advertising-supported programming which will be available to more than 90% of the metropolitan and urban areas of Western Europe.

The satellites will use space-proven, lightweight, cost-effective component designs based upon the highly successful RCA Satcom domestic communications satellites that have been in operation since 1975. Coronet will provide the only commercial satellite television in Europe beginning in 1986.

The satellites will be of the advanced Series 4000 type. The first launch is scheduled for autumn 1986 by Ariane 4 or the Shuttle. The second satellite will be available for 1987 to provide on-orbit back-up.

NEW INMARSAT MEMBER

Pakistan has become the 43rd country to join the International Maritime Satellite Organization; the Pakistan Telegraph and Telephone Department will represent the country.

Inmarsat is the international co-operative organisation that provides satellite communications facilities to the world's shipping and offshore industries. It is commercially-orientated, earning revenues from the sale of its services on a not-for-profit basis.

OTHER NEWS

ARGENTINA PLANS SATELLITE

Argentina plans to enter the space age with the launch of their first satellite, writes Joel Powell. A decision to build the solar research satellite will be made after the current final design phase is completed. A 500 km Sun-synchronous twilight orbit is planned for SAC-1 (Satellite de Aplicaciones Cientificas) spacecraft, which will weigh about 140 kg. A gamma ray spectrometer, solar flare neutron detector and a hard X-ray detector will comprise the scientific payload. The Argentinian space agency CNIS (Comision Nacional de Investigaciones Espaciales) began the project in 1981; no decision has been made on a launch vehicle.

CANADIAN CUTS

The Canadian government has cut $5 million (Canadian) from the National Research Council of Canada's space sciences budget, eliminating the sounding rocket programme and most of the balloon research, writes Joel Powell. Major satellite and Shuttle research projects were spared, but nearly a quarter-century of space research with the indigenous Black Brant family of sounding rockets appears to have been brought to an end.

MILESTONES

January 1985

16 Contact is lost with the UK satellite of the three-craft AMPTE set; 70% of the objectives have been met.

17 A drogue 'chute for the new lightweight Shuttle boosters fails in a drop test.

21 NASA's Goldstone antenna receives signals from the Soviet Vega Halley probes for the first time as part of the international tracking network.

24 Shuttle mission 51C is launched with Mattingly, Onizuka, Shriver, Buchli and Payton. They release a military satellite attached to an Intertial Upper Stage; IUS performance was slightly less than expected and small thrusters had to make up the shortfall. Landing at the Kennedy Space Center runway was successful on 27th, returning to the Orbiter Processing Facility the next day.

28 A memorandum of understanding on space collaboration between Britain and China is signed in London.

29 NASA names four commanders of future Shuttle missions: Francis Scobee (51L, November), Michael Coats (61C, December), Vance Brand (61D, January 1986) and Jon McBride (61E, March 1986).

29 The software for controlling the Skynet 4 satellite up to geostationary orbit is formally handed over by British Aerospace.

February 1985

1 The nuclear reactor of Cosmos 1607 is placed in a safe 14,400 km orbit, it is reported.

4 NASA is studying the benefits of using a second supplier for the Shuttle solid boosters.

4 NASA is requesting the delivery of Shuttle *Atlantis* for early April; and modified *Columbia* in early July.

5 ESA officially hands over control of Marecs B2 to Inmarsat for maritime communications; it is based at 176.5°E longitude to cover the Pacific. Marecs 1 (26°W) and Intelsat MCS-1 (62°E) cover the Atlantic and Indian Oceans, respectively.

7 NASA announces that Shuttle 51E, scheduled for 20 Feb, will now aim for a 3 Mar launch. The delay was caused by thermal tile replacement on *Challenger*. Mission 51D is also scheduled for March, to recover the LDEF satellite released in April 1984 by 41C.

8 The international COSPAS/SARSAT rescue satellite relay system has saved 350 lives since it began operation in 1982, presentingly using three Soviet and one American satellites.

13 McDonnell-Douglas are to build 28 PAM-DII upper stages for the USAF Navstar navigation satellite system.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

THE MARS DUAL ORBITER

By Dr. Fredric Taylor

The next phase in the exploration of Mars, after the Viking landers, can be accomplished with relatively simple orbiting spacecraft. A complementary pair in radically different orbits is the best way to address the outstanding scientific objectives; a possibility currently under discussion is for the US and Europe to provide one each. This, then, would be the first international planetary mission.

Scientific Interest in Mars

The exploration of Mars occupies a high position on the list of Mankind's endeavours. This (probably) lifeless planet resembles our own in so many other ways that its fascination is endless. Scientific questions about the origin of Mars, its interior structure, surface evolution and climate echo the most important problems facing Earth-bound geoscientists. These facts, and the accessibility of Mars as the Earth's near neighbour in space, caused the Red Planet to become the subject of frequent visits by unmanned spacecraft during the first few decades of deep space exploration.

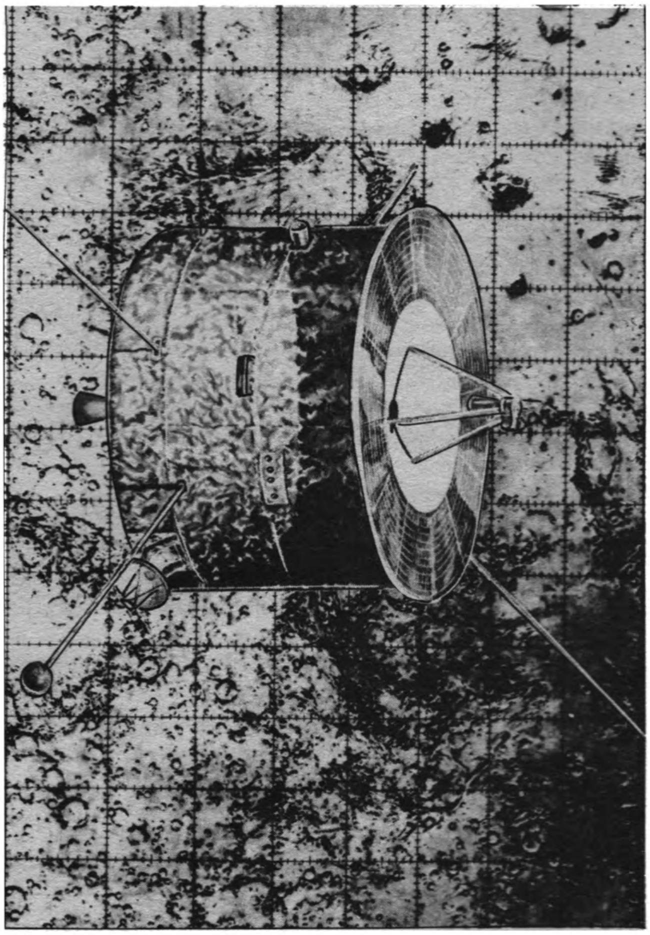
Viking

The first phase of Martian exploration culminated in the ambitious Viking project of 1976, which included placing two landers on the surface. These made it possible to study the surface at close range and to sample it chemically. Viking also made measurements of the detailed structure and composition of the atmosphere during the descent of the landers. Its meteorological stations remained active on the surface for several years and extensive photographic and thermal mapping coverage was obtained by Viking's orbiting and surface cameras.

Geochemistry and Geophysics

In spite of the great leap forward in our understanding that resulted from Viking and the missions that preceded it, most notably Mariner 9 in 1971, much about Mars

A possible configuration for the US Mars Orbserver. The relatively simple 'Planetary Observer' series of spacecraft will be based on existing Earth-orbiting craft, such as the NOAA weather satellites.

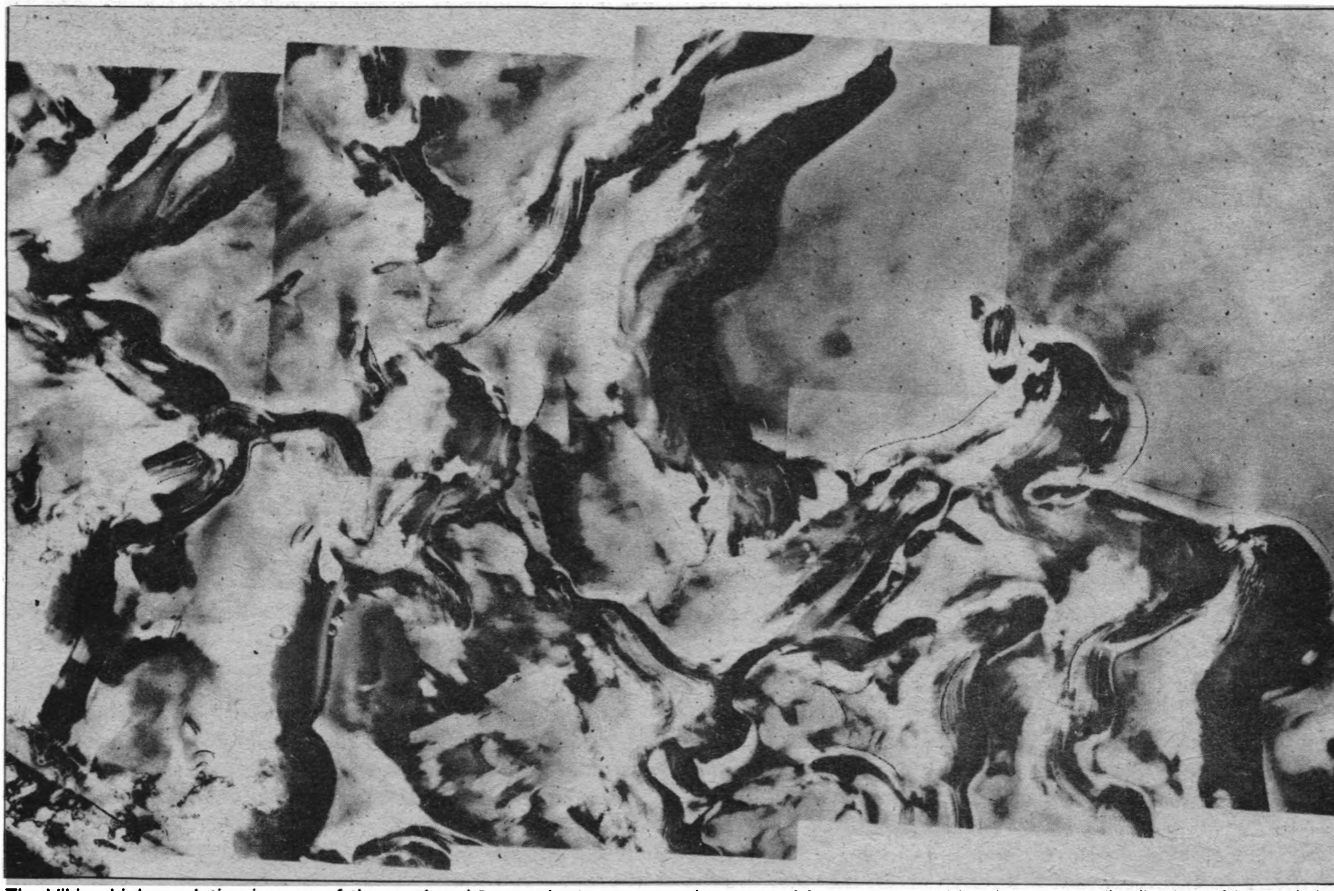


The Kepler Mars orbiter. *ESA*

remains mysterious. For example, very little is known about the geochemistry, the compositions and origins of the rocks and soils that occur in the various and varied regions of the planet. What minerals lie on and below the surface? Does Mars have a liquid interior? If not now, it surely did so once, as the giant volcanoes standing on the surface silently testify. What, then, has been the history of the evolution of the solid body of Mars as revealed by, for example, its present shape, or its magnetic properties?

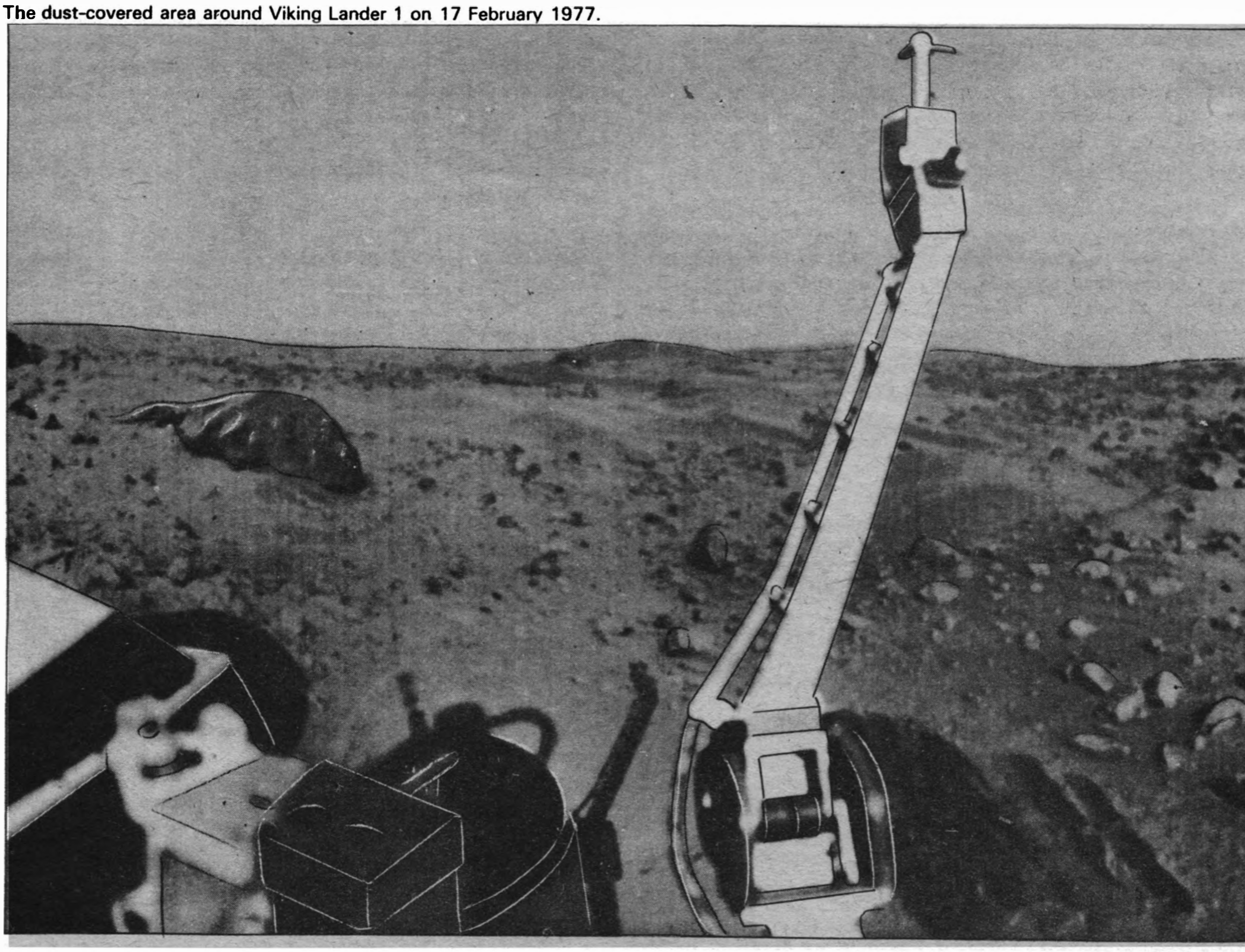
Climate

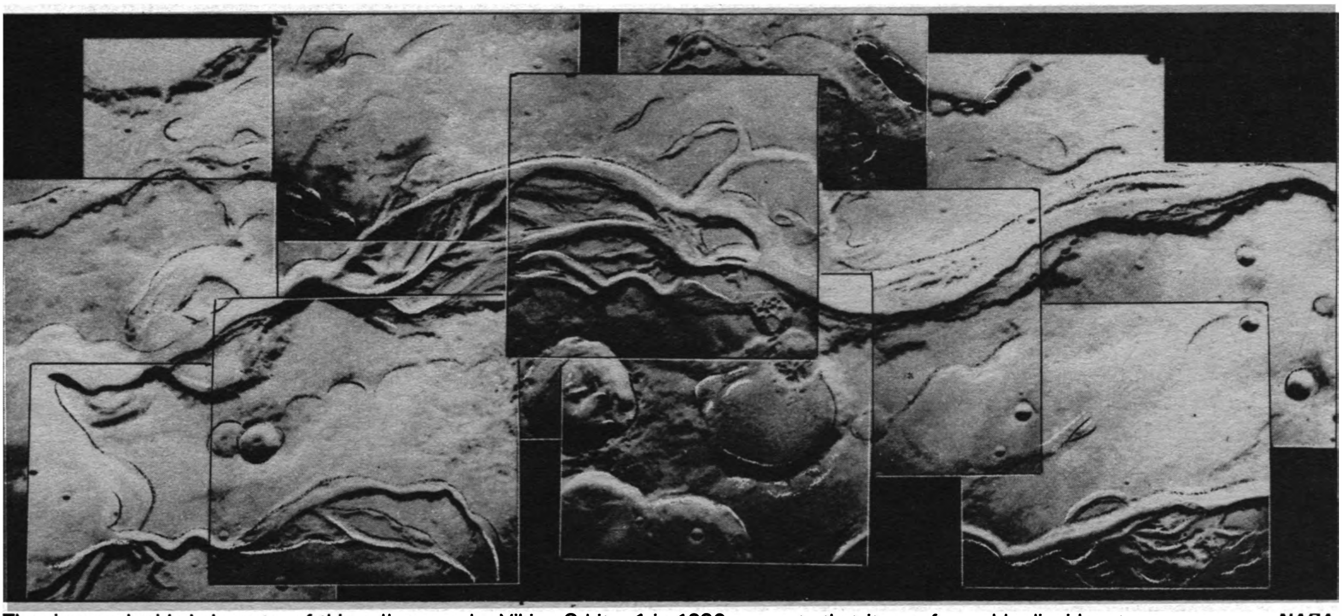
There is much interest now in the *climate* of Mars. The Viking pictures show quite clearly that running water once existed on the surface; the atmosphere must have been both warmer and denser then. In part, climatic change will result from periodic variations in the axial obliquity and orbital eccentricity of Mars, which occur on time scales measured in millions of years. Secular changes in the solar constant and other external variables might also be important. It is the way in whcih these are amplified by feed-back mechanisms in the atmosphere that are of particular interst at present. For example, a fairly small warming of the surface will release more frozen carbon dioxide and water into the atmosphere as the vapour phases; this enhances the warming by tending to prevent the main cooling process: radiation to space at thermal infrared wavelengths. This blanketing effect, usually called the 'greenhouse' effect, is responsible for the very high surface temperatures on Venus and is also important for maintaining the climate of the Earth. Nearly all of the climate-related processes on Mars (and Venus) are important on Earth. The physics of the process is the same in each case, of course.



The Viking high resolution images of the north polar cap show a spectacular array of features caused by the uneven distribution of ice and the exposure of layered material on slopes. *NASA*

The dust-covered area around Viking Lander 1 on 17 February 1977.





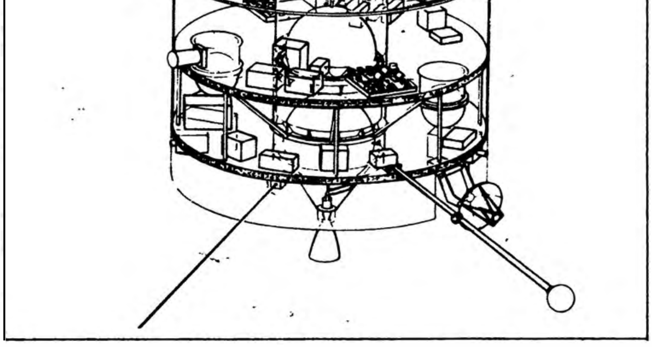
The sinuous, braided character of this valley seen by Viking Orbiter 1 in 1980 suggests that it was formed by liquid water. *NASA*

Volatiles and the General Circulation

Huge quantities of frozen water and carbon dioxide are held in the polar caps of Mars, and probably under the surface at more temperate latitudes, too. The latter, the 'permafrost' deposits, are thought to contain most of the water which once flowed on the surface. Their amounts and distributions, however, and their mobility (as glacial flows and through the atmosphere as vapour) are largely mysterious. The general circulation of the atmosphere itself has not been well explored. In addition to the overall pattern and its time variability, particularly with season, the role of waves is an important unknown quantity. These can be forced directly by the Sun (tides), by natural or 'free' modes of the atmosphere, or be produced by interference with the general circulation, for example by the flow over Mars' enormous topographical features. Waves are an integral part of the weather systems on any planet with an atmosphere.

Aeronomy

At very high levels in an atmosphere, where the pressure is perhaps one millionth of that at the surface, or less, the physical and chemical regimes are different from those that apply lower down. Diffusive separation of different molecular species can occur, as can ionization and dissociation. Very energetic short-wave radiation and particle fluxes from the Sun are involved in heating the atmosphere at these levels and for driving chemical reactions that produce unstable species such as ozone. The study of the processes involved is often called aeronomy. A knowledge of the aeronomy of Mars would lead to a better understanding of atmospheric loss rates, of the interaction of the planet with the solar wind and of the chemical balance that exists between the atmosphere and the surface. Although aeronomy traditionally deals with the outer layers of an atmosphere, some of the processes of interest are important all the way down to the surface on Mars. These are thought to include the dissociation of carbon dioxide, the principal constituent of the atmosphere; the continued existence of an atmosphere on Mars might depend on rapid recycling of the dissociation products back to carbon dioxide by mechanisms as not yet understood.

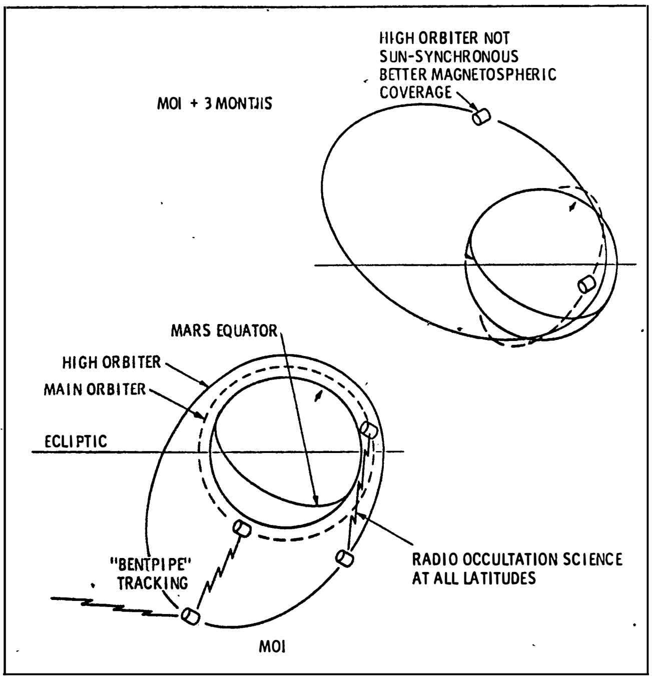


Plans for Future Exploration

The above brief outline describes some of the motivation for a renewed programme of Martian exploration. Not surprisingly, NASA's Solar System Exploration Committee included several missions to Mars when it laid out the Agency's plans for the next two decades. One of these, the Mars Observer, has already been authorised and is under active development for a launch in 1990. The next, Mars Aeronomy Orbiter, will follow a few years later. The Observer is a three-axis stabilised orbiter designed for mapping the surface and atmosphere to address questions of climatology and geochemistry. The Aeronomy Orbiter, on the other hand, will explore the volume of space near Mars and sample the upper atmosphere directly. This calls for a spinning spacecraft in a highly eccentric orbit, one that allows the orbiter to move thousands of kilometres away from Mars at apoapsis and to skim through the thermosphere some 150 km above the surface at closest approach. This close approach means that the upper atmosphere can be sampled directly by mass spectrometers, drag measurements and so on; the very eccentric orbit means that the Martian magnetosphere will be extensively explored.

Kepler

Interestingly, and symbolic of its importance, just before



Dual Spacecraft Mars Orbiter Geometry *JPL*

the SSAC announced its Aeronomy Orbiter concept, a group of European scientists proposed to the European Space Agency that it should study a very similar mission called Kepler. ESA agreed, and a Phase A study involving MBB, the German aerospace company, was carried out in 1982/83. The study showed that the mission was well within the scope of an all-European venture: it fitted ESA's budget, could be built entirely in European factories, launched on the existing Ariane 3 and tracked by European stations. Significantly, then, the Kepler study finally exorcised the spectre (already chastened by Giotto) that Europe did not have the capabilities nor the resources for its own programme in planetary science. In spite of this, ESA decided in 1983 to build an advanced astronomy satellite (ISO, the Infrared Space Observatory) instead. So whither Kepler?

The Mars Dual Orbiter

The dual orbiter concept was born in a meeting of the Joint Working Group on Planetary Exploration of the European Science Foundation and the US National Academy of Sciences. It was clear that if the Mars Explorer and Mars Aeronomy Orbiter could circle Mars *together* then a comprehensive assault could be made at once, on all of the next generation of critical scientific questions about Mars more efficiently and cheaply than in the SSAC plan. The spacecraft could be tracked and controlled by one team, perhaps even launched on a single rocket and could perform certain experiments (see below) that require two spacecraft at Mars together. Since Kepler and the Aeronomy Orbiter were nearly identical, why not make this the European component of a joint mission? Apart from the scientific gains, this would allow data to be returned from the first collaborative planetary mission a full decade sooner than other, more complicated, collaborative opportunities that were also being discussed. Meanwhile, NASA decided to go ahead with Mars Observer and ESA agreed to dust off the Kepler Phase A study and rework it in the context of a later launch, taking account of the Observer Mission.

Dual Orbiter Mission Operations

Some of the experiments that can be performed with two spacecraft together in Mars orbit involve sending signals from one to the other. For example, a radio beam of suitable wavelength can be used to probe the atmospheric temperature and ion density profiles. Two spacecraft tracking each other's *positions* can determine the gravity field of Mars, and hence its shape and internal mass distribution, with remarkable precision. It has been suggested - so far without detailed analysis - that the Dual Orbiter might obtain the first measurement of the mass of ice in Mars' polar caps that way.

Another major category of two-spacecraft experiment involves the study of the interaction of the solar wind with the planet. The near-space environment of Mars, filled with complex particle streams and field lines, varies continuously in space and time. Only with two simultaneous measurements at different locations can the effects begin to be separated into their different contributions. For example, the magnetic field surrounding Mars is due in part to the field from the interior and in part to induced fields in the magnetosphere. The latter tend to travel and the former to be stationary; it takes two spacecraft to measure the travelling component and so resolve the two.

Mapping and imaging of the surface and atmosphere is always a highly regarded part of a planetary mission. With two orbiters in different orbits, this can be steroscopic or, more easily, the lower orbiter can obtain very detailed imaging of a local feature (such as a canyon or a dust storm) while the camera further aloft puts this picture into a global context by obtaining a panoramic or synoptic view. The camera under design for the European orbiter would detect objects as small as a few metres across on the surface of Mars but could cover less than 1% of its area during the course of its two-year lifetime because of restrictions on total data volume. The lower resolution camera on the other spacecraft could cover the whole planet.

Prognosis

The future of the Dual Orbiter mission will be decided later this year when ESA's scientific committees decide which project should follow ISO. Kepler must compete with exciting scientific opportunities in solar and terrestrial magnetospheric physics and X-ray astronomy. The high cost of ISO has already pushed the earliest date for a launch to Mars to 1992, whereas NASA say they can launch the Observer in 1990, and intend to do so. Still, the smaller Kepler can follow a faster, 'type 1,' trajectory and reach Mars in time to overlap the nominal Observer mission by five month and the extended mission by two years - plenty of time for all of the scientific objectives to be met. If it succeeds, the Dual Orbiter could be followed by joint European-US robots to explore the surface, by sample return missions and, ultimately, manned colonisation and exploitation. If it fails it will do so in the committee rooms of Europe and, probably, we shall not in our lifetimes see any real awakening of planetary science on the continent that dominated the field for centuries.

Meanwhile, the Soviets are also revitalising their programme of Mars exploration and will launch a new mission to orbit the Red Planet and approach closely to Phobos. Some of their measurements, made as they must be from an equatorial orbit close to that of the inner moon, are highly complementary to the objectives of the Mars Observer and Kepler, both in polar orbits. If the Soviet orbiter is long lived enough, or if it is delayed or if it is followed up in subsequent launch windows, we may yet see an international Mars *Triple* Orbiter, with scientists world-wide united in a peaceful voyage of exploration.

THE ESA SCIENCE PROGRAMME

By Gordon Whitcomb

ESA has the potential to carry out an exciting variety of scientific space missions. The author, Head of the Future Science Programmes Studies Office of ESA, described some of the possibilities to the Society's Space '84 conference last November.

Background

To date, the European Space Agency (ESA), together with its predecessor the European Space Research Organisation (ESRO), has launched a total of 13 scientific spacecraft, ranging from simple spinning spacecraft such as Esro 1 and 2 to the complex 3-axes stabilised Exosat with its advanced data handling and control systems. In development are a further five spacecraft which will be launched between 1985-1992. These missions were selected through a competitive cycle of activity during which proposals were:

- submitted by the science community,
- studied both by peer groups and by ESA,
- some eliminated as being too complex, expensive or of limited scientific value,

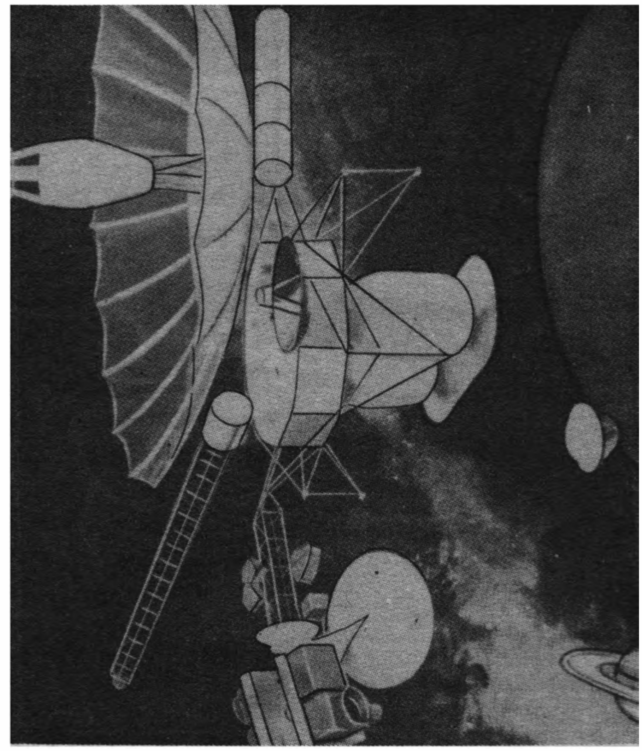
leading to

- selection of a mission for development.

The approach was adequate while missions were relatively modest in their technical demands. However, in recent years the needs of the scientists have increased to the point where the old approach is no longer suitable, since larger and more complex missions cannot be accommodated easily in the selection cycle. Recognising the need for change, ESA has undertaken a long term planning exercise to establish a mission selection strategy for the 1990's.

Future Mission Strategy

The future scene for space science in the European context is centred on the concept of major missions, designated as 'cornerstone missions,' which serve as the framework around which the total programme is formulated. The cornerstones are defined as missions that stimulate scientific and engineering achievement and which, if realised, will place Europe in a leading position. The need for such a goal-oriented approach for science stems from an analysis undertaken by a committee of senior scientists [1]. This committee, after consideration of more than 70 independent proposals for missions, selected four major activities as being of particular relevance to the aims of European space science. Missions associated with these four 'cornerstones' are expected to be launched in the 1990's at intervals of three to four years.

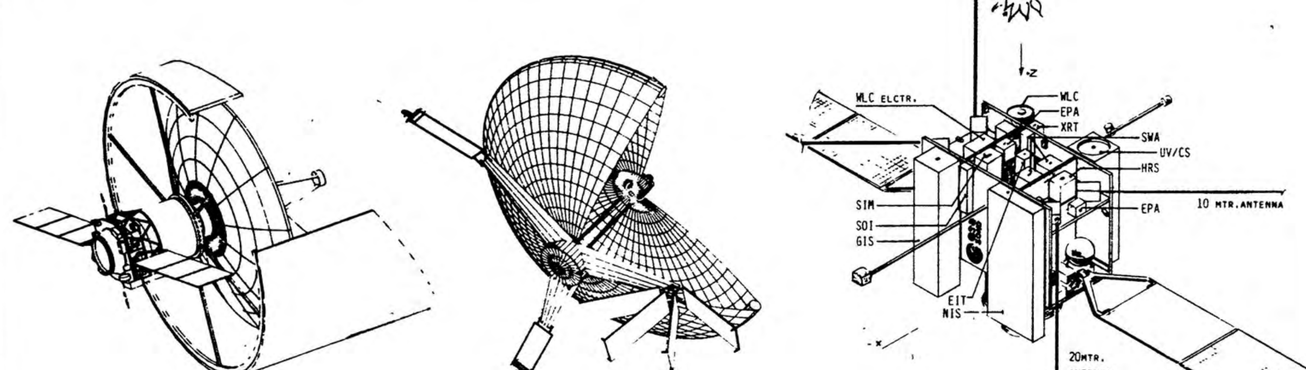


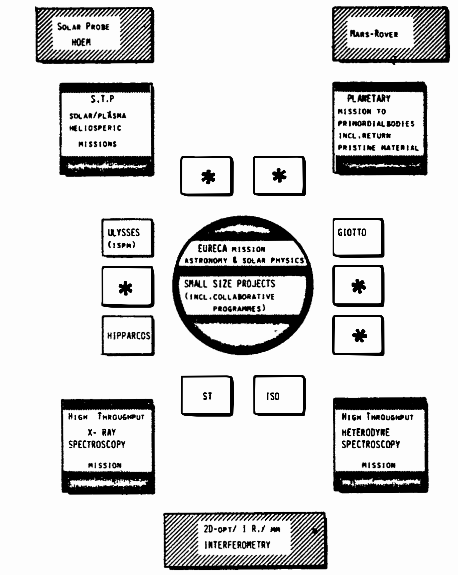
Cassini, a Saturn orbiter/Titan probe in cooperation with NASA, is a possibility for a European project. *NASA/JPL*

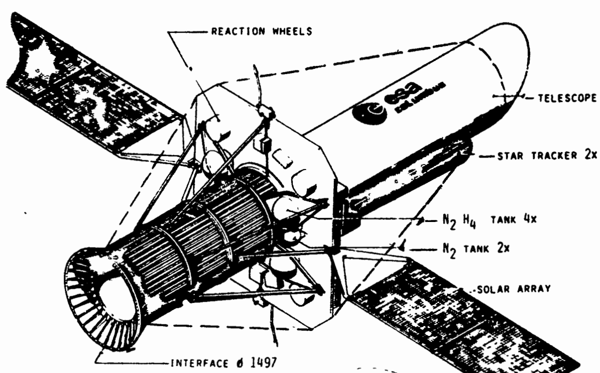
In the intervening years other, more modest, missions will be launched. These will be selected in the traditional competitive manner from among proposals submitted by the science community. Missions such as small planetary orbiters, probes, small X-ray missions on retrievable carriers or larger cooperative missions that require a modest share of the available funds, are expected to fly. The current expectation is that, subject to funds being available, a total of 11 can be launched in the years from 1990 to 2005.

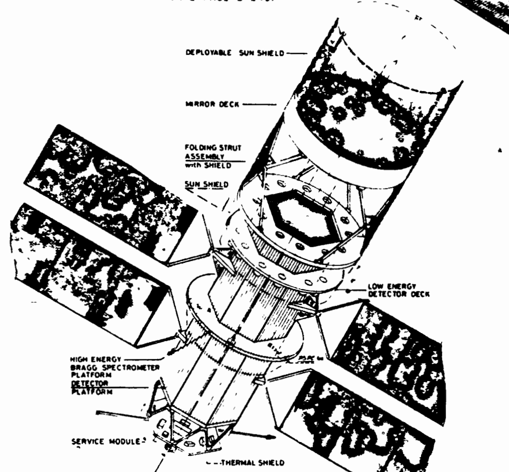
Beyond 2005, more advanced missions such as Mars-Rovers, large optical interferometers and solar probes are foreseen. The technologies for these will be developed in the 1990's.

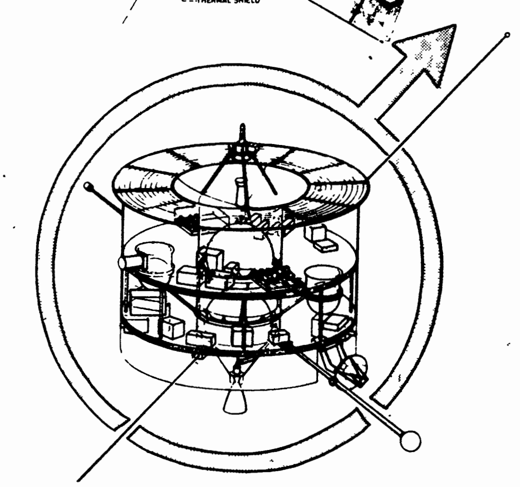
From left: the Far Infrared Spectroscopy Telescope (FIRST), Quasat and SOHO concepts. *ESA*



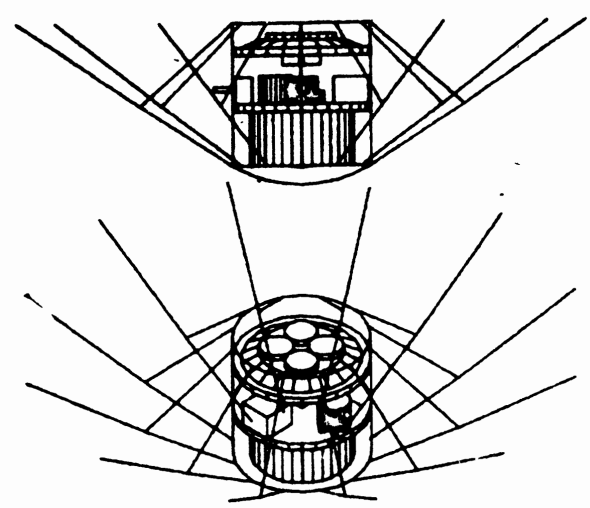








From top: the cornerstone philosophy, Columbus, the X-ray Multi-Mirror mission (XMM) and the Kepler Mars orbiter. ESA



Cassini: Titan entry probe with deployed decelerator.

The Current Menu

Cluster
Simultaneous studies of the magnetosphere using four spacecraft. Particular emphasis on study of the polar cusp. Four simple spinnig spacecraft each of about 250 kg mass.

Soho
Solar spectroscopy in the 100-500 Å band. Solar seismology. Study of the inter-planetary medium. Observatory type of spacecraft, mass 1900 kg, 3-axes stabilised. Stationed at the L1 Libration Point 1.5 million km from the Earth.

Kepler
Detailed studies of the Martian atmosphere and magnetosphere. Simple spinner, 400 kg in Mars orbit.

Candidates for Selection in 1987

Columbus
Spectroscopy in the 900-1200 Å band. Large telescope; Mass ± 2500 kg; 48 hour elliptic orbit.

Quasat
Very long baseline interferometer at 21 GHz, in conjunction with a network of ground based radio telescopes. 15-20 m inflatable antenna on a 3-axes stabilised spacecraft; Mass ± 1000 kg.

Cassini
Study of the atmosphere of the Titan Moon of Saturn. Atmosphere entry probe carried on a Mariner Mk 2 mothership. Probe is released from Saturn orbit.

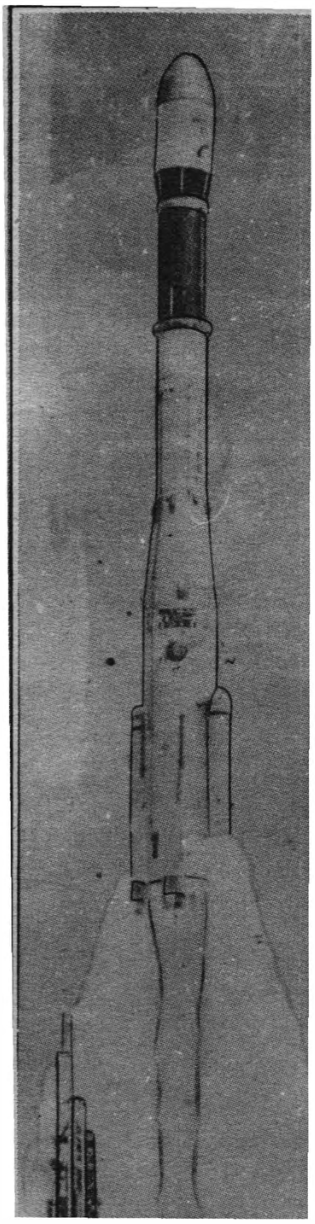
Additional missions may be added to this list.

Beyond 1987

XMM
X-Ray Spectroscopy. Large Observatory; Multiple mirror Telescope with about 20 separate mirror systems; Mass: circa 4000 kg; Length: circa 10 m.

First
Heterodyne Spectroscopy at sub-mm wavelengths. Possible Space Station user; Large Deployable Antenna; Cryogenic cooled instruments.

Agora
Asteroid Rendezvous. Large Solar Arrays; Ion Drive System; Mass: circa 2500 kg.



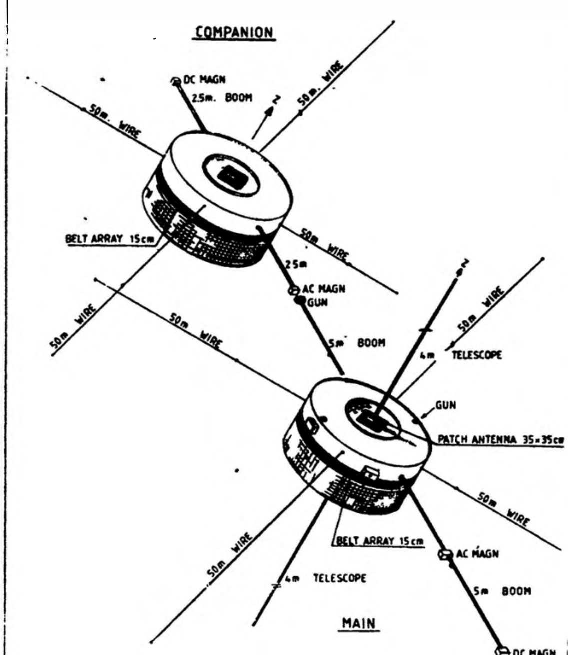
ESA/ESRO Scientific Spacecraft Launched

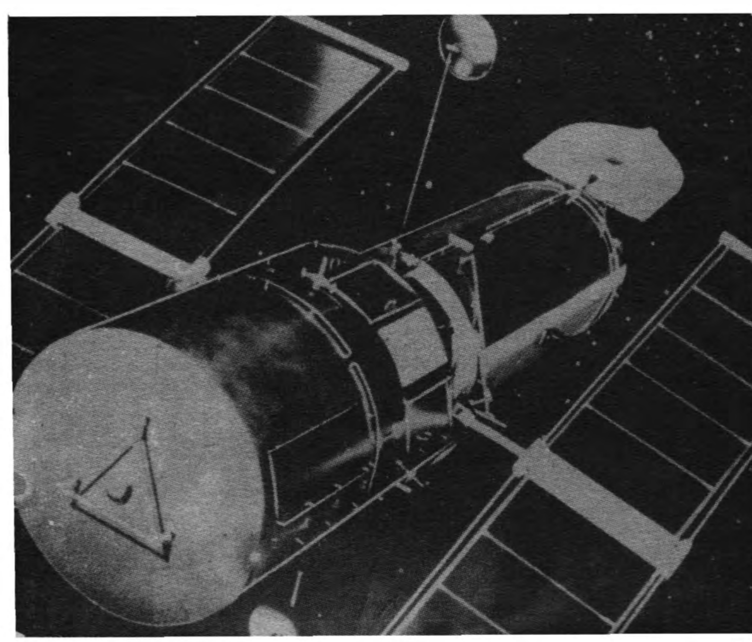
	Launch	End life	Mission
Esro-II	May 68	May 71	Cosmic rays, solar X-rays
Esro-IA	Oct 68	Jun 70	Auroral and polar cap phenomena, ionsophere
Heos-1	Dec 68	Oct 75	Interplanetary medium, bow shock
ESRO-1B	Oct 69	Nov 69	As Esro-IA
Heos-2	Jan 72	Aug 74	Polar magnetosphere, interplanetary medium
TD-1	Mar 72	May 74	Astronomy (UV, X-and gamma-ray)
Esro-IV	Nov 72	Apr 74	Neutral atmosphere, ionosphere, auroral particles
Cos-B	Aug 75	Apr 82	Gamma-ray astronomy
Geos-1	Apr 77	June 78	Dynamics of the magnetosphere
Isee-2	Oct 77		Sun/Earth relations and magnetosphere
IUE	Jan 78		Ultraviolet astronomy
Geos-2	Jul 78		Magnetospheric fields, waves and particles
Exosat	May 83		X-ray Astronomy

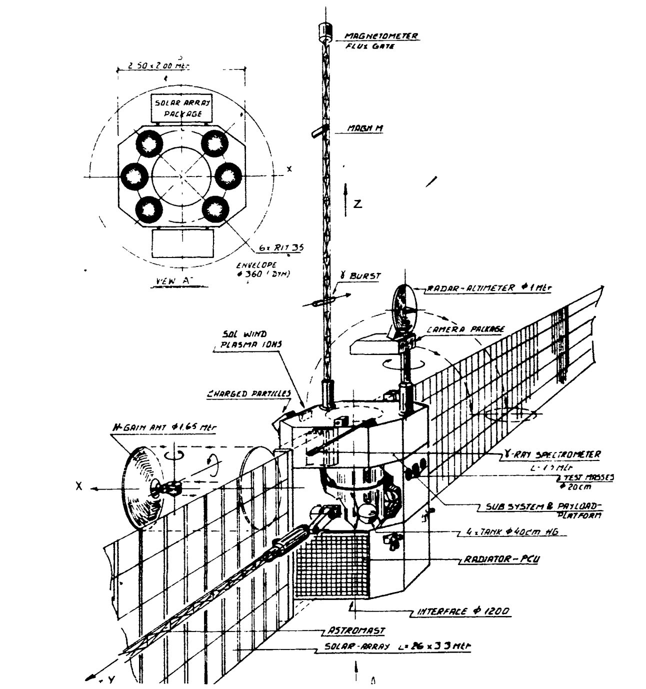
ESA Science Missions in Development

Title	Mission	Launch Date
Giotto	Study of the composition of the Comet Hälley	1985
Hipparcos	Precision measurement of the angular separation between several thousand known stars thus giving an accurate 'roadmap' of the Universe.	1988
Space Telescope	Provision of the faint object camera as a focal plane instrument on the NASA Hubble Space Telescope. This camera is sensitive enough to detect planets around nearby stars.	1986
Ulysses	Study of the interplanetary medium in an 'out of ecliptic' plane. The spacecraft will swing-by Jupiter then traverse the polar region of the Sun.	1986
ISO	Infra-red astronomy in the 5-100 micron band. Spacecraft carries a 60 cm cryogenically cooled telescope.	1992

The Ariane launcher will be used for a deep space mission for the first time this July when it launches ESA's Giotto Halley's comet probe. ***Below left:*** **the Cluster satellite concept.** ***Below right:*** **ESA is providing the Faint Object Camera for NASA's Hubble Space Telescope.** ***ESA***







The Agora asteroid craft concept. *ESA*

Cornerstone Missions

The four 'cornerstones' are:

1. a Solar Terrestrial Physics Programme (STP)
2. a High Throughput X-Ray Spectroscopy Mission
3. a Heterodyne Spectroscopy Mission,
4. a Primitive Body Mission.

The Solar Terrestrial Physics Programme might consist either of several small to medium size satellites such as the Soho and Cluster missions, currently in the ESA planning cycle, or retrievable missions on an orbiting platform. The objectives are to further Man's understanding of the Sun-Earth system through studies of the Sun, the interplanetary medium and the Earth's magnetosphere. The programme, although achievable within Europe, could form part of a global programme in cooperation with other agencies such as NASA, ISAS (Japan) and IKI (USSR). Discussions with these agencies are in progress and, if successful, could lead to an international programme of ten or more separate spacecraft operating simultaneously to give detailed spatial and time correlated data.

The three other 'cornerstones' are expected to be single spacecraft missions characterised by their advanced technology and long lifetimes.

The High Throughput X-Ray Spectroscopy mission will extend the already advanced field of X-ray astronomy. It is complementary to the NASA AXAF mission but would be Ariane-launched into a low Earth orbit from which it would operate as an observatory. The spacecraft would carry several independent but closely aligned telescopes, perhaps 20 or more, each consisting of a number of grazing incidence X-ray mirrors and associated focal plane instruments. The realisation of such a mission will present a major challenge to institutes and industry as the scale of production and the scale of the spacecraft assembly, integration and testing are beyond the current European experience.

The Heterodyne Spectroscopy cornerstone could be a derivative of the 'First' mission. This has been assessed by ESA as a free flying mission to carry out spectroscopy in the 200 micron to 1 mm wavelength range. This band has not as yet been explored, although the USSR is expected to launch a spacecraft in the late 1980's. The expectation is that the ESA spacecraft could be flown in the mid- to late-1990's after results from the Soviet mission and the European ISO (1992 launch) are available. Current thinking is that telescopes could be attached to the NASA Space Station; studies of this option are in progress.

The final cornerstone, the Primitive Bodies mission, could be based either on the Agora concept or could be a more ambitious comet and asteroid multiple rendezvous mission, in cooperation with NASA or other agencies. Such missions will require new technologies for ion drive systems, solar arrays, autonomous operations and data handling techniques. In the event of cooperation with NASA, an attractive option for Europe would be to provide an 'intelligent' ion drive module which would include the ion thrust assemblies, the attitude and orbit control systems and the power subsystems. The development of such a module would give Europe a useful 'contribution element' for several potential cooperative missions. Examples are:

- Primitive body sample return
- Mercury orbiters
- Out-of-Ecliptic, large telescopes, and
- Large solar probes.

The Current Menu

The adoption of the 'cornerstone' policy will be progressive over the coming years as funds become available. However, the current study programme contains elements that are representative of the missions foreseen in the 'cornerstone' philosophy. Studies of these will continue in preparation for selection in 1985 and 1987 of spacecraft for development.

For the 1985 selection we have three candidate missions: Cluster, Soho and Kepler, while for 1987 the list includes Columbus, Quasat and Cassini but may be extended to include other candidate missions.

Beyond 1987, missions such as the XMM, First and Agora are in preparation. These are major missions and could become elements of the conerstones strategy. As such, the emphasis for these missions in the coming years will be on the development of fundamental technology such as manufacturing techniques for multiple grazing incidence mirrors, high surface accuracy antennae and ion propulsion techniques.

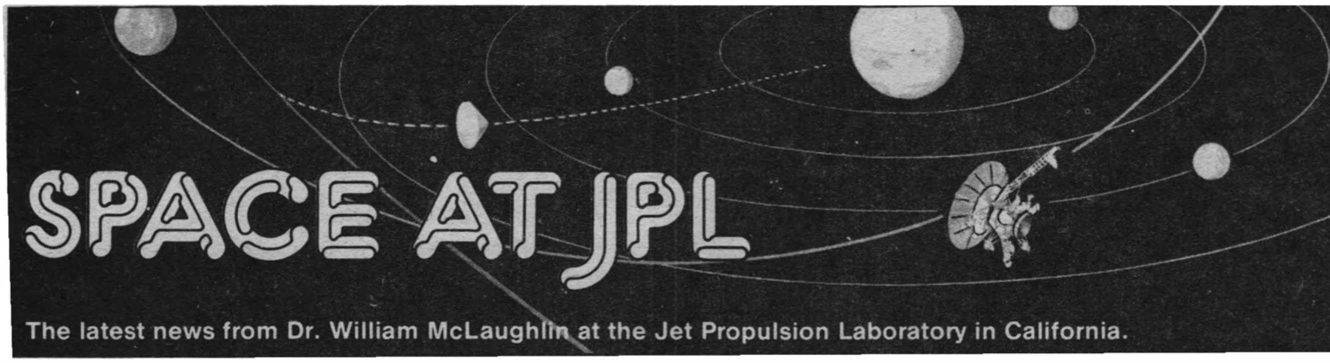
Conclusion

The programme outlined represents a sound basis for the development of European expertise in space science over the coming 20 years. Both industry and scientific institutes will benefit from such a programme which will satisfy, to some extent, the need for scientific and technological progress. The programme, however, cannot be carried out without a modest increase in the present funding for ESA space science (7% per annum over the next five to six years). Discussions are in progress within the member states and decisions on the funding level are expected in the course of 1985. If agreement is reached and the increase is approved, European space science can look forward to a healthy and competitive future.

Without the increased funds ESA can maintain a small programme of activity but will be unable to provide European scientists and industry with missions of stature except *via* cooperation in a secondary role with stronger, more active Agencies.

REFERENCE

1. *Horizon 2000,* Report of the Survey Committee ESA Publication, July 1984.



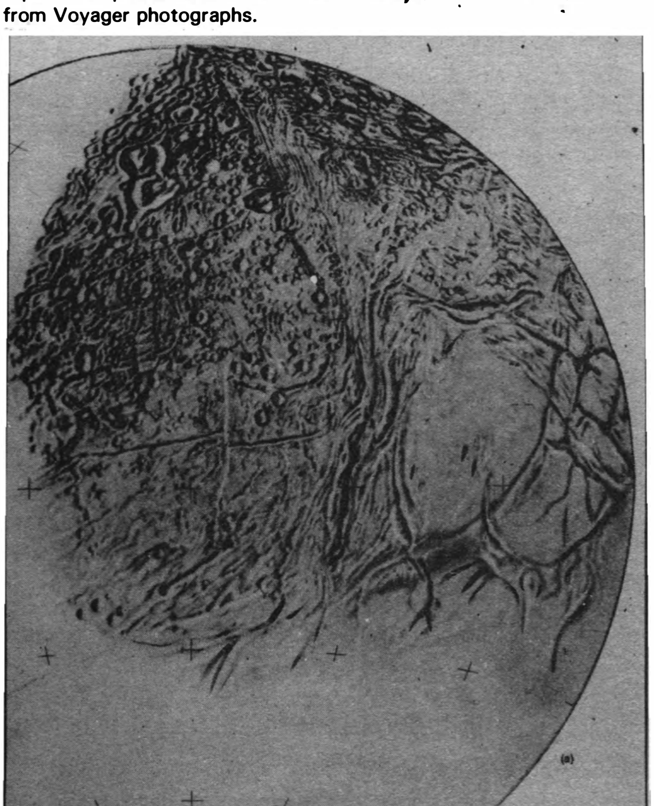
SATURN AND SETI

Getting acquainted with the satellites of other planets is a slow and difficult process. The first stage, discovery, has stretched over three centuries in the case of Saturn; Huygens found Titan in 1655 and the Voyager spacecraft were still identifying new satellites in the early 1980's. Determination of the orbit and physical properties such as mass and diameter begins the second stage, characterisation, for a satellite once its existence is known.

However, in one sense, a satellite does not really seem to become a possession of the civilised world until it is mapped. Mapping is as much a territorial rite as it is an act of illumination. Hence with broad-based pleasure we greet a new book: *Voyager 1 and 2 Atlas of Six Saturnian Satellites* by Raymond M. Batson and seven associate authors (NASA SP-474).

The six satellites are Mimas, Enceladus, Tethys, Dione, Rhea and Iapetus. Saturn has at least 17 satellites, but Titan is cloud covered, small irregular satellites do not lend themselves readily to standard cartographic representation, and Voyager did not pass close enough to some satellites to map them adequately. A separate chapter is devoted to each object and includes physical data, maps of topographical features with named landmarks and altitude/longitude gridding, and the set of Voyager photographs used to compile each map. The collection of photographs is enhanced in value by an associated coordinate system for each photograph that permits rapid correlation between images and maps.

A partial map of the Saturnian satellite Enceladus has been constructed from Voyager photographs.



Six appendices add to the book's authority with the ones on image processing, mapping and feature nomenclature of particular interest. On the Saturnian satellites the names of the features are taken from the great epics and legends of the world. Thus, names on Dione are taken from the *Aeneid* of Virgil, while the *Odyssey* of Homer is used as a source for Tethys, and the French *Song of Roland* provides nomenclature for Iapetus. There is a crater named Ali Baba on Enceladus and Morgan (Le Fay), King Arthur's sinister half sister, is commemorated on Mimas.

Another new book, *Cosmic Quest* by Dr. Michael Klein and Margaret Poynter (Atheneum, New York), takes us from Saturn to SETI: the search for extraterrestrial intelligence. Klein manages the SETI project at JPL and Poynter is a writer of non-fiction.

The book is not a technical treatise and presupposes no particular knowledge of SETI. It starts with a historical survey of attitudes towards life and intelligence in the Universe - from Aristotle through to Tsiolkovsky and Drake - and works through the necessary background in astronomy and biology. Klein's insider's knowledge of SETI provides perspectives on the subject that are not usually found in surveys of an elementary nature. This one is recommended for its throughtful and fresh approach to an area that often suffers from perfunctory exposition.

VENUS RADAR MAPPER MISSION

The Venus Radar Mapper (VRM) mission will begin with an April 1988 launch and subsequent insertion into an elliptical orbit about Venus in late July of that year for the purpose of mapping most of the planetary surface with a high resolution radar. The project is managed by JPL for NASA. Major systems contracts have been let to the Martin Marietta Corporation for the spacecraft and the Hughes Aircraft Company for the synthetic aperture radar.

Since the project status was last reviewed in this column, in the December 1982 and July-August 1983 issues, considerable progress has occurred. The 'preliminary design review' is a standard tool employed in the development cycle of a project to ensure that the details of a design are well understood and agreed upon by all parties before fabrication begins. A preliminary design review was held for the radar subsystem last September, followed by a similar milestone for the spacecraft in October. A second review of the radar system is scheduled

for March; the first one concentrated upon subsystem design while the second will review expected system performance. A preliminary review of the mission design will be conducted in May.

At least 70% of Venus will be mapped by VRM with a goal to mapping 92% of the surface; the Soviet Veneras 15 and 16, now in orbit, are expected to map about 25%. Since VRM and the Veneras obtain their highest resolution at differing portions of Venus, the projects are complementary. The equivalent optical resolution for VRM will range from 250 m to 700 m (per line pair), while the Veneras are in the 1 to 2 km range. The Pioneer Venus Orbiter (NASA) has yielded coarse radar imagery (40-80 km) of about 40% of the surface. All of this mapping, and some done from the ground as well, is part of an effort to characterise the geological state of Venus to the same degree that the geology of the Moon and Mars is known. For an up to date analysis of scientific questions see Dr. R.S. Saunder's paper in the October 1984 issue of *JBIS*.

In addition to producing images, the radar system will be employed as an altimeter in order to obtain a global topographic map of Venus.

The spacecraft will also conduct gravitational measurements in order to assist in better understanding the internal structure of the planet. Venus is more gravitationally homogeneous than the Earth, more like a 'billiard ball' than the decidely oblate shape of our planet. The gravitational experiment will be accomplished in the usual fashion by careful analysis of radiometric tracking data in order to deduce the effect of the gravitational field of the planet upon the VRM trajectory.

The mapping strategy for VRM has been designed so as to minimise spacecraft complexity and, hence, cost. The orbit is highly elliptical with a periapsis (closest approach to Venus) altitude of approximately 250 km and an apoapsis of around 7800 km. For just over 36 minutes, about the periapsis region of each orbit, the radar will be employed in the collection of data. Then, for approximately 111 minutes, the data will be transmitted back to Earth. The remaining time in the 186 minute orbit will be used for calibration and for turning the spacecraft; the entire vehicle will be reoriented each orbit so that its (fixed) antenna points towards Earth for transmission of the data. This intentional procedure is quite similar to the *ad hoc* strategy employed by Shuttle *Challenger* last October when its steerable antenna did not function properly. The whole Shuttle had to be periodically reoriented to transmit the radar data from the SIR-B experiment back to TDRS orbiting overhead (see February's 'Space at JPL'). In the case of VRM, the procedure is required because the same 3.7 m high-gain antenna is used for data collection and for data transmission.

The mass of the spacecraft will be approximately 1030 kg after it has been inserted into orbit about Venus. Power for the craft and the experiments is provided by two solar panels with an area of 10.2 m^2, producing at least 1188 W at the end of the 243 day mission. Data storage will be on two tape recorders, each having a capacity of approximately 3.6 x 109 bits. The data are normally played back to Earth at a rate of 268.8 kilobits per second. For comparison, the highest data rate of Voyager was 115.2 kb/s, at Jupiter, and will be 29.9 kb/s at Uranus. The Earth-orbiting Infrared Astronomical Satellite (IRAS) played back the data from its tape recorders at the rate of 1000 kb/s.

Launch will be from the Shuttle with a Centaur G as upper stage. Insertion into orbit about Venus is by use of a STAR-48 solid rocket motor. The VRM project is sponsored by NASA's Office of Space Science and Applications. John Gerpheide is the JPL project manager and Dr. R.S. Saunders is the project scientist.

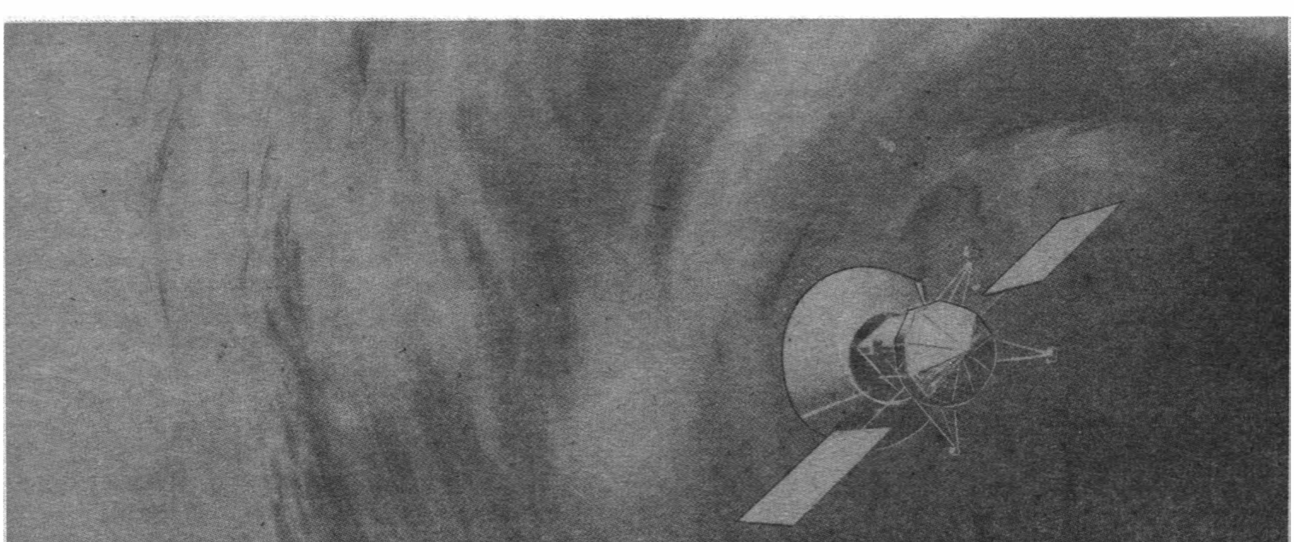
TWO ENCOUNTERS FOR VOYAGER

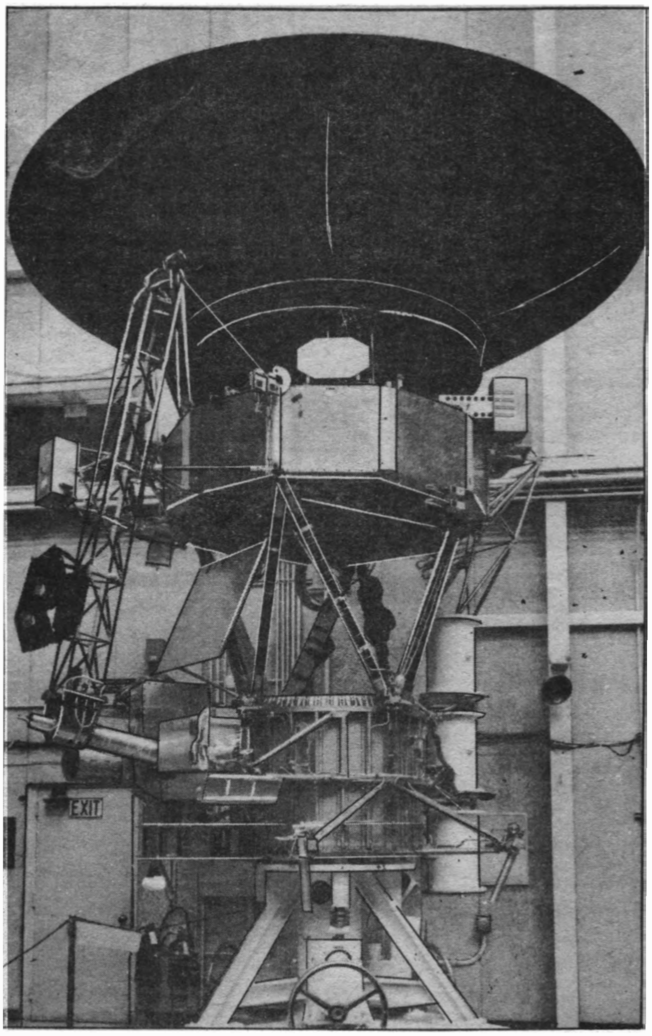
On 13 November 1984 the trajectory of Voyager 2 was adjusted slightly for its January 1986 encounter with Uranus. This was accomplished by turning on the engine for somewhat over 10 minutes, yielding a velocity change of about 1.54 m/s.

The resultant change in the trajectory will amount to approximately 40,000 km at Uranus with a time-of-travel difference of 39 minutes. Two more manoeuvres are scheduled for Voyager 2 prior to its closest approach to Uranus on 24 January 1986. The next will take place about one month prior to closest approach and the last will be done at only five days before encounter. The purpose is to position the spacecraft accurately on its chosen path through the Uranian system.

After each manoeuvre, Voyager is carefully tracked by antennae of the Deep Space Network in order to gauge the actual effect of the correction and plan subsequent ones. Valuable additional information will also be obtained

In this artist's conception the Venus Radar Mapper is shown in its exploration of the second planet in 1988.





The Voyager spacecraft were, of course, extensively engineered before launch. However, numerous enhancements have been made to the onboard software of the spacecraft so that now, over seven years after launch, Voyagers 1 and 2 have had their performance capabilities significantly increased.

for the navigation process by measurements taken by the spacecraft's cameras as they image Uranus and its satellites against the background of stars.

The Voyager Navigation Team, headed by Dr. Donald Gray, estimates that it will be able to deliver the spacecraft to within 100 km of the desired location with respect to Uranus. After the encounter, based upon careful analysis of tracking data, the Navigation Team will be able to determine the actual place of delivery to about 2 km. This accuracy in both delivery and reconstruction is vital to the success of observational planning and analysis, respectively.

The trajectory correction manoeuvre last November represented the first time that Voyager's engine had been turned on in over three years, the last time being just after the encounter with Saturn in order to set course of Uranus.

The other Voyager spacecraft, Voyager 1, has no further planetary encounters in its future, but there have been some recent indications that, nevertheless, it may be approaching an encounter with another type of object: the heliopause.

The heliopause is the predicted boundary region between the solar domain and interstellar space where the solar magnetic field and solar wind phase into the interstellar fields and particles environment. It has been estimated that the heliopause might lie between 50 and 100 AU from the Sun (1 AU, or astronomical unit, is the distance from the Earth to the Sun, approximately 150 million km).

Voyager 1 is now about 22 AU from the Sun, but for some time it has been detecting radio waves (at about 3 kHz) that could represent emission from the heliopause region. Writing in the 1 November issue of *Nature,* W.S. Kurth (U. of Iowa), F.L. Scarf (TRW), D.A. Gurnett (U. of Iowa) and R.L. Poynter (JPL) speculate that these measurements might indicate that the heliopause is at the low end of the estimated distance. Voyager 1 would cross this region in the early part of the next decade.

It is a measure of the scale of expansion of our knowledge to realise that, in 1958, JPL's Explorer I satellite investigated the electromagnetic neighbourhood of our Earth a few hundred kilometres above the surface (Van Allen's discovery of the trapped radiation belts). Now, four spacecraft (two Voyagers and two Pioneers) are eliciting the structure of the entire Solar System at a range of tens of astronomical units.

WORLDS IN MINIATURE

A recent, special issue of *JBIS* was devoted to the subject of world ships (June 1984). A world ship is a hypothetical vehicle that traverses interstellar space in a rather leisurely fashion and has a self-contained, bioregenerative life support system.

The prospects for long-term manned missions, even at a less ambitious level than that of world ships, would be enhanced by an understanding of the behaviour of materially isolated biological systems. A modest NASA programme, 'Controlled Ecology (Human) Life Support Systems' (CELSS), is addressing some of the relevant questions. This month's review of an advanced concept will focus upon some work that has been done at JPL in support of CELSS.

A materially closed, energetically open ecosystem is a balanced system with living components that is sealed off from the environment with respect to the transport of all matter, but may exchange energy with the rest of the Universe. To date only four types of materially closed ecosystems are definitely known to have persisted for years: those of Clair Folsome (University of Hawaii), Bassett Maguire, Jr. (University of Texas), Joe Hanson (Jet Propulsion Laboratory), and the Earth itself.

Joe Hanson is not currently funded by CELSS, but he keeps in his laboratory about 25 sealed flasks that contain materially closed ecosystems in various states of development. The oldest was closed off in June 1980. Hanson constructs his small worlds from four components: shrimp, algae, bacteria and brackish water (with a lower salinity than sea water).

The shrimp in Hanson's ecosystems are somewhat over 10 mm in length and feed upon the plants (algae) and the bacteria, producing organic wastes and carbon dioxide in the process. Bacteria decompose organic wastes into their inorganic constituents and produce more carbon dioxide in the process. The algae use the carbon dioxide along with light from outside the system for their growth. If a shrimp dies, it becomes organic waste and is broken down into its inorganic constituents by action of the bacteria. All of this activity takes place in one litre flasks about half full of the synthetic brackish water.

The key to the balance and self-regulatory action of the ecosystem is that it is resource limited so that if one component, the algae for example, attempts to grow to excess, it is held in check by another component; such as limits of carbon dioxide or other inorganics. Nevertheless, Hanson observes that there is an amazing diversity in

evolution of his ecosystems.

Although most of Hanson's systems balance nicely and live for years - it is not known if there is any limit on their lifetime - upon occasion an ecosystem will lose a component or die altogether. For example, some systems lose their shrimp while the other parts remain alive.

Considerable popular interest has been generated by the research; closed ecosystems are available commercially and the work has been featured on television and has been reported in a variety of newspapers and magazines. In January 1982 an invitational workshop on closed system ecology was held at the California Institute of Technology. The workshop, organised by Hanson and sponsored by NASA's Office of Space Science and Applications, was attended by researchers from several universities throughout the US and by NASA representatives. In the proceedings of the workshop Dr. Folsome, who is a professor of microbiology at the University of Hawaii, remarked: 'Materially closed ecosystems offer an infinity of miniature worlds which can closely model or can depart from that one world which is our terrestrial ecology (Earth). As a direct consequence, the variety of research topics which can be based upon the concept of materially closed systems is enormous and of potential value to almost any field of science, pure and applied.'

Folsome has constructed materially closed ecosystems using microbes (but no larger animals such as Hanson's shrimp) that have functioned for longer than 17 years. These systems are particularly convenient for study through continuing measurement of parameters, such as oxygen concentration, that characterise the state of activity (a technical reference for this type of investigation is contained in a 1981 paper by E.A. Kearns and C.E. Folsome in the journal *BioSystems*, **14**, pp.205-209).

Whether long-term manned missions eventually draw upon the lessons to be learned from studying these flasks of self sufficiency, or whether even world ships will be able to trace their heritage back to a few litres of fluid in a laboratory cannot, of course, be foretold. However, it is clear that the understanding of the dynamics of spaceship Earth could certainly be advanced by pursuing the beginnings made by Hanson and his colleagues.

MICRO-SPACECRAFT DESIGN

Limits are constantly being tested in astronautical engineering: data rates increase, pointing accuracy improves and propulsion systems become more efficient. A limit that is not as obvious is that of spacecraft size. How small can a useful interplanetary vehicle be made?

Robert Forward, in his science fiction novel *Dragon's Egg*, envisaged a spacecraft only 5 mm in diameter, but it had a mass of over 200 million tonnes! Inhabitants of neutron stars have unusual requirements. Thirty years ago James Blish also wrote of a very small vehicle, on the millimetre scale, but he too dealt with an imaginary world of small creatures in his short story *Surface Tension*.

In the real world some years ago, Caltech professor and Nobel laureate Richard Feynman offered a cash prize for the creation of an operable electric motor that would fit within a 1/64 inch (0.4 mm) cube. An ingenious builder quickly won the prize and the motor is on permanent display under a microscope at Caltech, where it spins at the touch of a button. Today, microcircuits are moving into the realm of microns and a further diminution, down towards the scale of atoms, can be imagined.

My colleague James D. Burke is a normal-sized human and, to the best of my knowledge, so are his associates. Despite this handicap, they have completed a study aimed at investigating the virtues and problems inherent in designing a real micro-spacecraft.

The principal benefit to be obtained from a small spacecraft is the requirement for minimal energy to accelerate it to a given speed. In addition to this dynamical advantage related to mass, small geometrical size would facilitate storage onboard a launch vehicle of a larger host spacecraft. Also, small structures are inherently more shock resistant than similar, larger ones.

Burke and his design team did not attempt to achieve the absolute minimum in size but they did attain better than an order of magnitude reduction from representative current spacecraft. They found that a spacecraft with a mass in the range of 20 to 30 kg could perform adequately to support certain scientific missions in deep space. For comparison, the joint ESA/NASA Ulysses mission to study the Sun employs a 370 kg spacecraft, the Voyager 2 interplanetary vehicle now has a mass of 788 kg, and the Galileo spacecraft will have a mass of approximately 2550 kg (this includes propellant and 335 kg due to the probe) when it is launched to Jupiter in 1986.

Two limitations on the reduction of spacecraft size are furnished by the antenna and power-generation susbsystems, assuming solar rather than nuclear power.

The best performance could be obtained using a very high frequency radio system to communicate with Earth. The K_a-band, at 31 GHz, might be available in the near-term future. At present, X-band (8 GHz) and S-band (2 GHz) are employed by most spacecraft. With a K_a-band system, calculations show than an antenna as small as 0.1 m^2 would fulfill communications requirements at a range of 2 AU (an AU, or astronomical unit, is the distance from Earth to Sun). It would be possible to transmit a few kilobits per second with this system: a data rate that would comfortably support most fields and particles experiments.

Power usage was held down in the micro-spacecraft design and only 30 W were required. For comparison, Voyager is at present a consumer of up to 400 W of power. Photovoltaic cells to supply this modest need could be fitted on to the basic square spacecraft structure of only 65 cm on a side developed by Burke's team.

Several options exist for controlling the attitude of the spacecraft in flight so as to be able to point its antenna to Earth; the team settled upon the use of tiny pulsed plasma thrusters.

The size of electronic components imposed no constraints on the micro-spacecraft design since micro-electronic circuitry is already available due to computer-technology requirements.

One suitable mission would be to assume a position behind the Sun and transmit X-band and K_a-band signals through the solar corona to investigate coronal properties. Dr. H. Porsche of DFVLR, West Germany, has developed the rationale for such a mission.

Other applications would include missions where multiple spacecraft would be helpful in characterising, more or less simultaneously, an extended volume. Micro-spacecraft could be delivered in this case from a single-source launch or transport vehicle. Tiny, rugged landers could be placed on planetary surfaces. Another class of missions would be those with orbits having high energy requirements. It would also be an advantage to employ a micro-spacecraft in solar sail applications in order to obtain the maximum benefit from that low-thrust device.

Further enhancements for micro-spacecraft might include an extremely high frequency communications system using optical technology, tiny radioactive power sources and an all-solar attitude control system with solar vanes like those carried on the Mariner 4 mission to Mars (see 'Space at JPL' in the January 1985 issue).

NEWS FROM ESA

STATUS OF PROJECTS

The three spacecraft ESA/NASA International Sun-Earth Explorer (ISEE), mission continues to return valuable data. The ISEE-3 spacecraft, re-named International Cometary Explorer (ICE), has been manoeuvred in order to cross the tail of comet Giacobini-Zinner in September 1985.

GEOS 2 is now in a slightly asynchronous orbit and visible from the ESOC ground station for only four weeks every three months. Data acquisition is funded by Germany and Switzerland until August.

IUE: more than 200 proposals have been received for the 1985 observation period with the International Ultraviolet Explorer; it was reported that, technically, the mission lifetime could be extended to 1988/90.

Exosat: the X-ray astronomical satellite payload and spacecraft hardware status has remained constant since October 1984, with good performances of the medium energy experiment, the gas scintillation proportional counter and one of the two low energy imaging telescopes.

Giotto is scheduled for launch in July to intercept Comet Halley in March 1986. The mission is being coordinated with the space missions of the USSR and Japan and with the International Halley Watch.

Ulysses, formerly the International Solar Polar Mission, is planned for launch in May 1986. A potentially serious problem is the possibility that the radio-isotope thermoelectric generators (RTGs) may have to be fitted with a blast shield to protect them against a possible explosion on the launch pad. Depending on the solution chosen, there may be cost and schedule problems.

Space Telescope/Faint Object Camera: the camera has been delivered to NASA and is undergoing integrated system tests. Launch is scheduled for mid-1986.

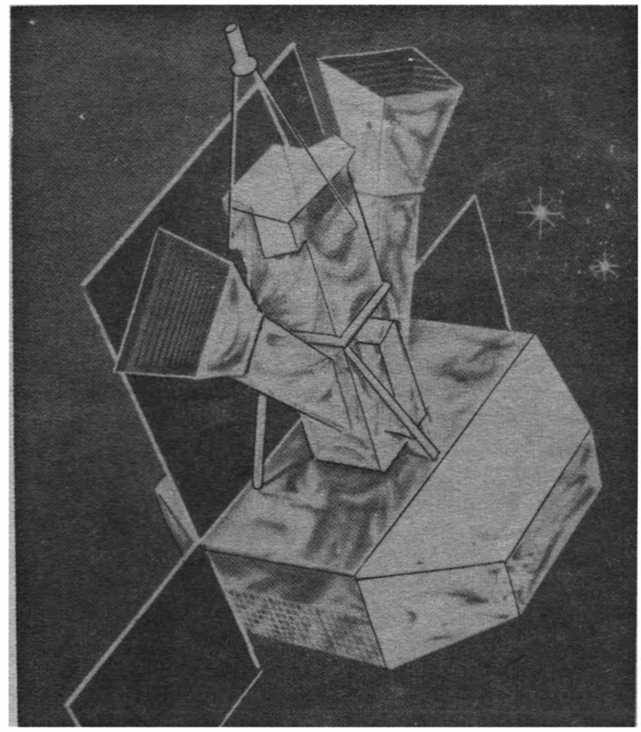
Hipparcos: two meetings of the scientific selection committee have reviewed the scientific proposals to the Agency and their recommendations have now been largely implemented by the Input Catalogue Consortium. The activities for the delivery of the Input Catalogue to the Agency a year before launch (presently foreseen for early 1988) are on schedule.

Infrared Space Observatory: the Phase A conclusions are being re-examined; Phase B is expected to start in the autumn of 1986. At their meetings on 12 and 13 February the Astronomy Working Group and the Space Science Advisory Committee began the evaluation and selection procedure for the focal plane instruments.

The multi-disciplinary Mars orbiter mission, Kepler, will be a candidate at the end of 1985 for selection as the next scientific project. The Phase A study is currently being updated, in particular to ensure that the mission complements the Mars Geoscience and Climatology Orbiter mission of NASA.

Under study at Assessment level are Cassini and Agora. Cassini is a potential collaborative mission with NASA comprising an orbiter of Saturn and a Titan entry probe; ESA's contribution would be the Titan section. The Assessment study of Agora, a mission to rendezvous with a number of main-belt asteroids, is being revised to examine the possibility of cooperation with NASA.

The long range plan calls for a 'cornerstone' in planetary science consisting of a mission that will return comet or asteroid samples to Earth for laboratory analysis. A joint ESA/NASA Primitive Bodies Science Study Group has started to develop a strategy in this field, taking into account the missions to Comet Halley and NASA's planned Comet Rendezvous and Asteroid Fly-by (CRAF) mission. The Group is currently focussing attention on Agora and a coma sample return mission as possible 'stepping stones' towards the ultimate goal of a comet nucleus sample return mission.



Hipparcos will measure the positions of up to 100,000 stars with unprecedented accuracy. *ESA*

Spacelab and Eureca: although there are no new initiatives under consideration for the use of Spacelab, five instruments in the space science field have been accepted for flight on the recently approved first flight of Eureca. Efforts are under way to set up a programme of Eureca missions as proposed in the long term plan for space science. Some adaptation of the Eureca platform would be desirable to make it more suitable for space science disciplines.

RETROSPECTIVE ON 1984

1984 did not see the launch of any ESA scientific satellites. The most significant event was the elaboration by the Survey Committee and Topical Teams of a Long Term Plan to the end of the century, issued in July 1984 as *Space Science Horizon 2000.*

Further important significant events were the completion of the environmental tests of Giotto and the delivery of the Faint Object Camera to NASA for integration in the Hubble Space Telescope. NASA has issued an Announcement of Opportunity for new scientific instruments for the Telescope; ESA will not respond to this AO itself, but it will take the necessary measures to allow a decision to be taken in 1987 on a potential development of an FOC copy or of an updated version. European scientists, conversely, can respond to the AO directly to NASA by the due date of 17 May.

On the Infrared Space Observatory, the Call for Experiment Proposals and for Mission Scientists was issued to the scientific community in Europe and the US in the latter part of 1984. Hipparcos has fully entered its development phase with the signature, just before Christmas, of the prime contract document.

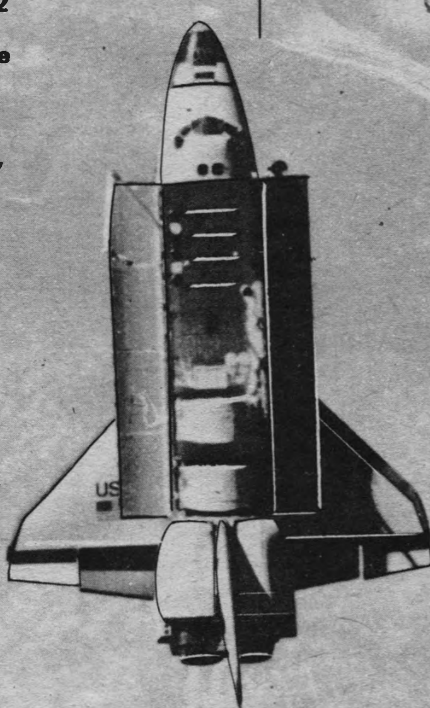
SOCIETY BOOKS

PROJECT DAEDALUS

The publication of the Project Daedalus Final Report marked the end of years of painstaking work by a group of BIS pioneers. The BIS received congratulations from around the world for its far-sighted project: designing a probe for man's first crossing of interstellar space.

The Final Report Report contains 24 papers spread over 192 large-format (A4) pages, summarising the four year study. The papers cover the overall spacecraft design, mission profile, computer systems, navigation, experiments and our knowledge of nearby stellar systems, some of them possibly with planets.

"Daedalus" is acknowledged as a milestone in the the development of advanced astronautics. Copies of the Report cost just £7.00 ($11.00) post free.



THE EAGLE HAS WINGS

An exciting progression of space achievements in the years following the Second World War led to Man's first landing on the Moon in 1969. Rockets for probing the upper atmosphere evolved into the space launchers we know today. Vanguard, Explorer, Atlas, Titan, Mercury, Gemini, Apollo – a succession of names to conjure up memories of the 50's and 60's when man was taking his first tentative steps into outer space.

The Eagle Has Wings tells the story of the major US Space projects from 1945 to the watershed year of 1975, when the Apollo missions came to an end and the first wave of interplanetary exploration gave way to the more sophisticated probes of today. Written by *Spaceflight* managing editor Andrew Wilson, it is packed with information and photographs. It runs to no less than 144 large-format pages and can be obtained for the low price of £7 ($11.00) post free.

HIGH ROAD TO THE MOON

Every member ought to own a copy of this unique 120 page publication which records many of the Society's early ideas and discussions on Lunar exploration in the visionary drawings and illustrations of the late R. A. Smith.

Pictures and drawings detail plans for orbital rockets, space probes and ships to take men to the Moon and Lunar exploration. Some are familiar illustrations used in books of the time: others have not been published before.

Bob Parkinson has brought these pictures together with a commentary which tells how the pioneers imagined things would be and how they actually were. It goes beyond the present, for man's involvement with the Moon is not yet finished. Using the Smith pictures as a background, Dr. Parkinson looks at the possible future for the Moon and how it might be brought about.

Price: £6.00 ($9 .00) post free.

All of the books are available from: The British Interplanetary Society, 27/29 South Lambeth Rd., London SW8 1SZ, England

DAEDALUS:

A NEW VIEW

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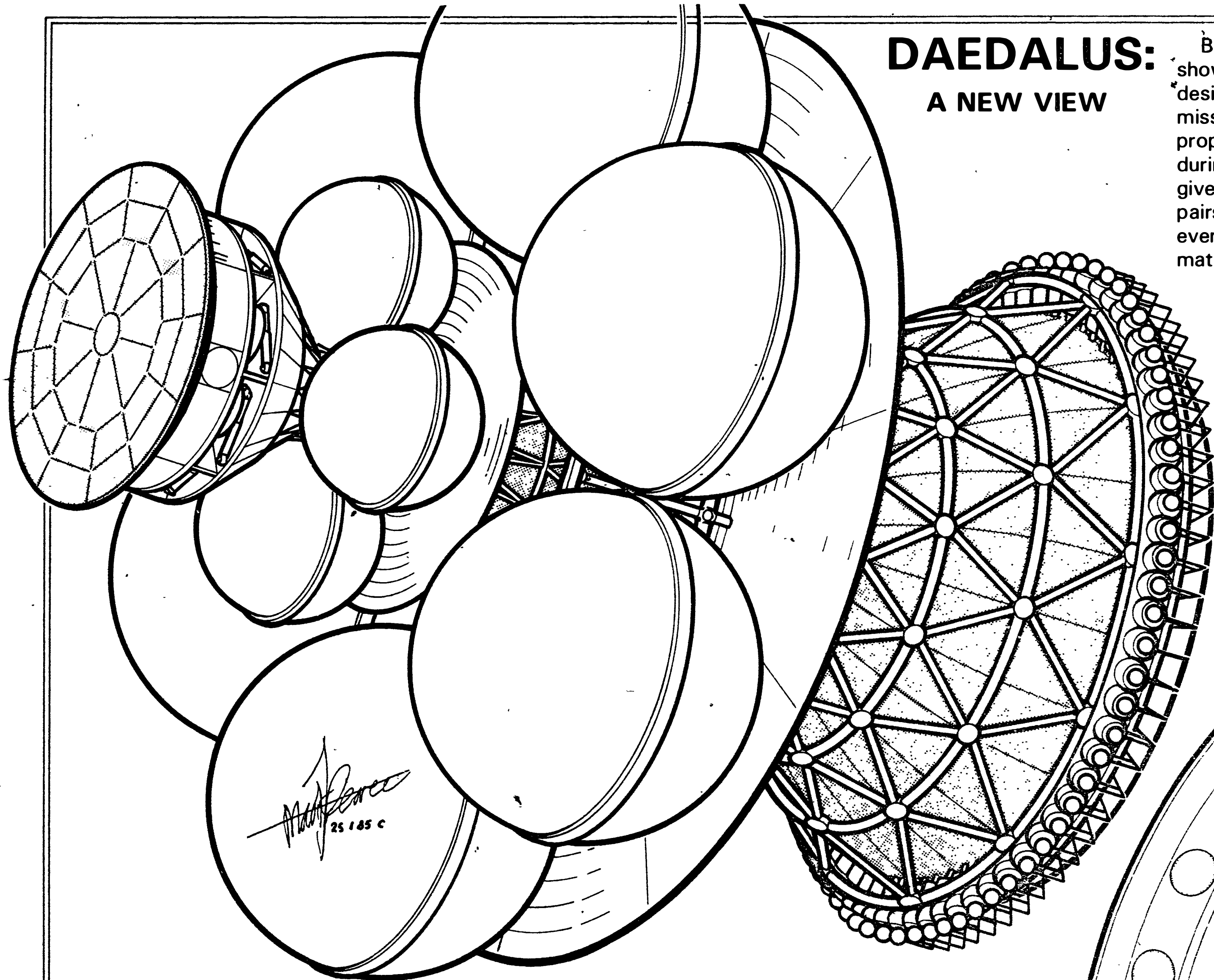

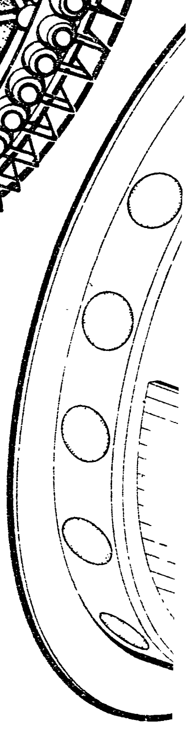

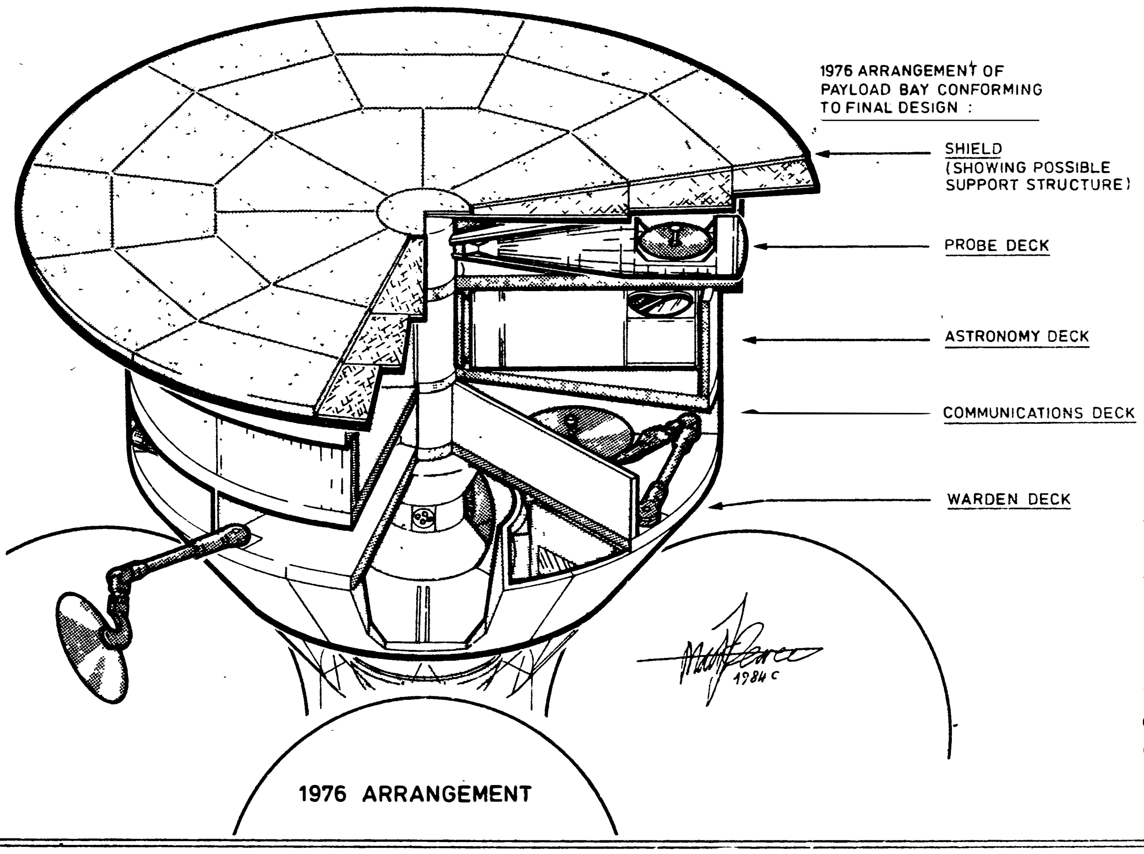

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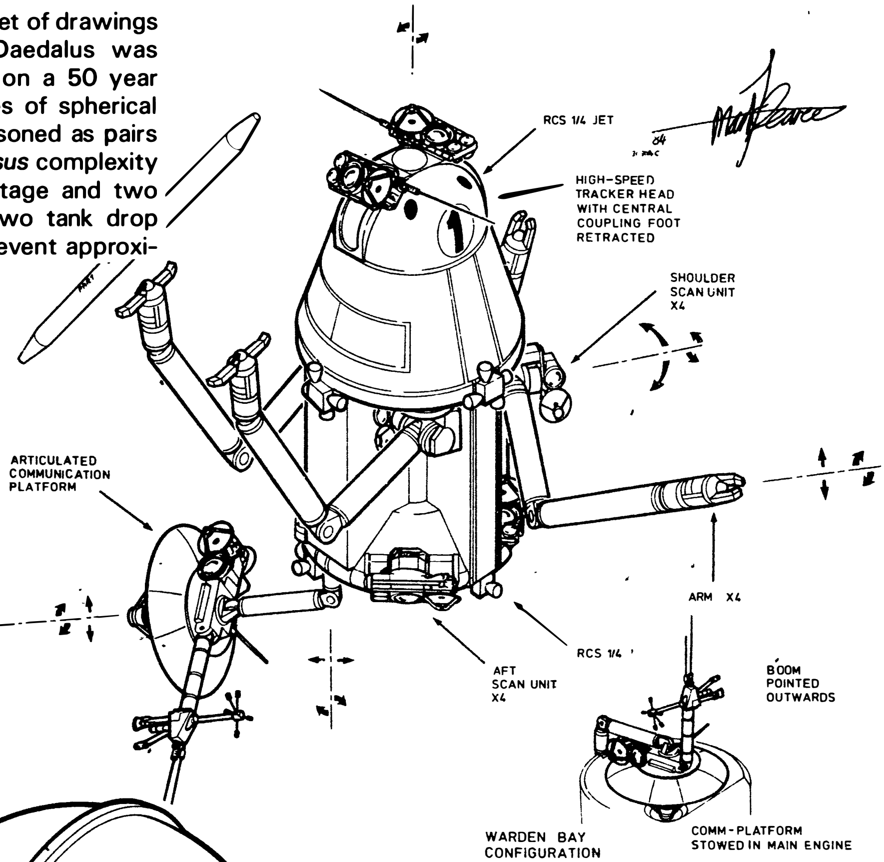
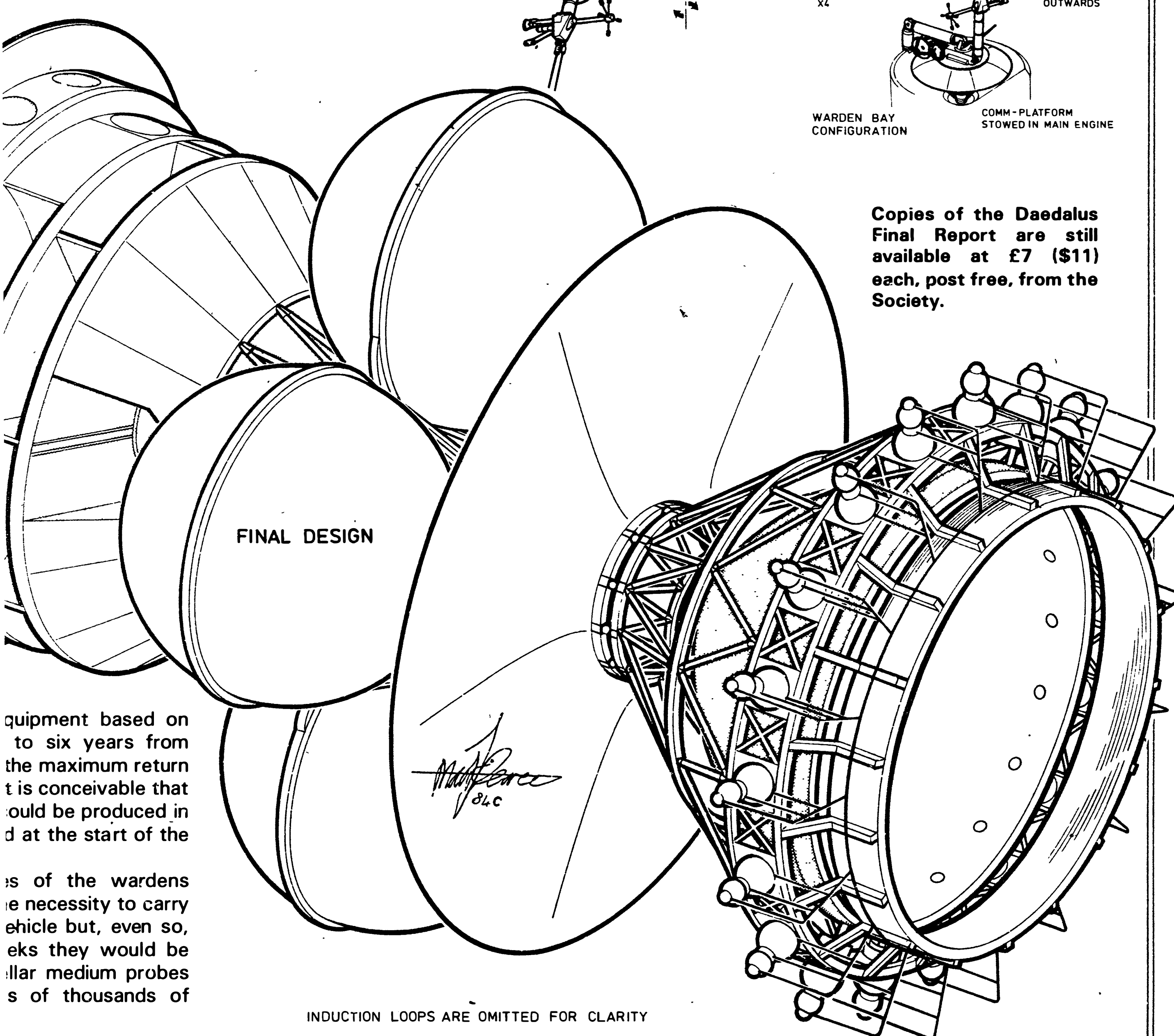


Copies of the Daedalus Final Report are still available at £7 ($11) each, post free, from the Society.



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THE VEGA MISSIONS

By Phillip Clark

In December 1984 the Soviet Union launched two probes, representing the most ambitious interplanetary mission it has so far attempted. The two craft, Vega 1 and 2, will reach Venus in June and then fly on to meet Comet Halley in March 1986.

Introduction

There is some ambiguity about the naming of the Venus/Halley missions, in that they are called both 'Vega' and 'Veha.' this results from the Soviet alphabet: the names are composed of the first two letters of Venus and Halley. However, the Soviets do not have a letter 'H,' and they usually use 'G' instead. Therefore, 'Halley' becomes 'Galley' and 'Veha' becomes 'Vega.' The latter is used here since 'Vega' has an astronomical connection (the star Alpha Lyrae).

The Flight Plan

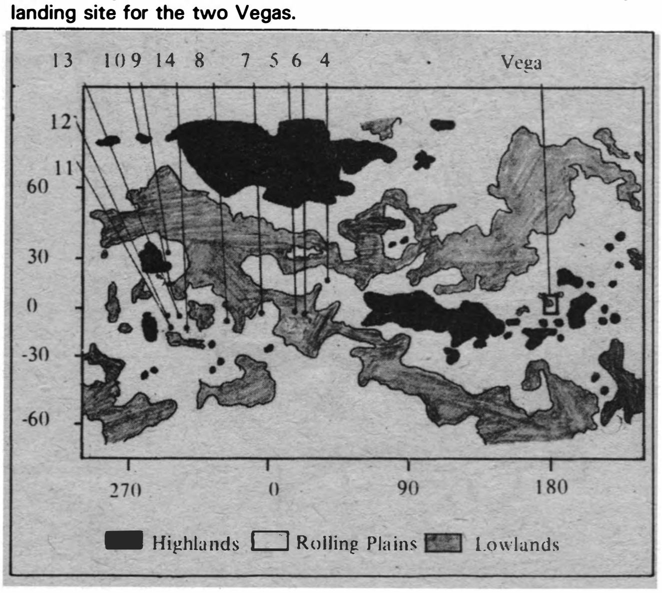
The two probes were launched on 15 and 21 December 1984, timed to arrive at Venus on 14 and 18 June, respectively. They will fly past Venus, probably at distances of about 35,000 km, after separating descent craft. Each descent module carries a free-floating balloon and a soft-landing craft. The main bus will be directed towards encounters with Comet Halley, arriving in March 1986, passing within about 10,000 km of the nucleus and returning data throughout the encounter phase.

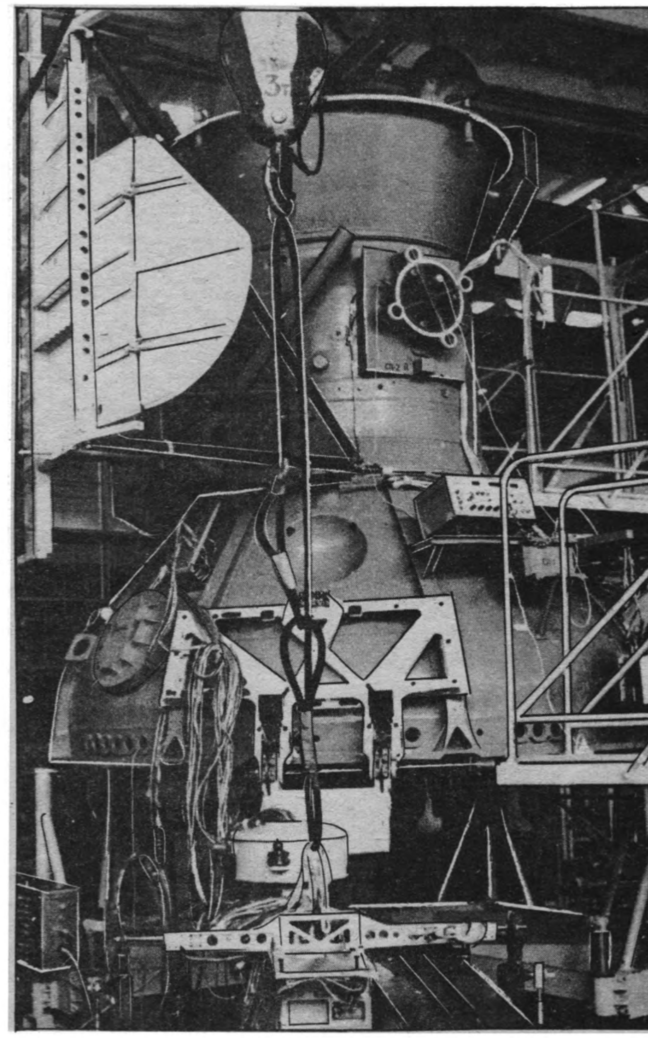
The craft are regarded as pathfinders in that Vega 1 will be the first to encounter the comet, although five vehicles will be launched to an intercept. The encounters in 1986 will be:

Vega 1 (USSR); 6 March (10,000 km)
Planet-A (Japan); 7 March (200,000 km)
MS-T5 (Japan); 8 March (1 million km)
Vega 2 (USSR); 9 March (3,000 km)
Giotto (ESA); 13 March (100-500 km)

The Japanese MS-T5 was launched on 7 January 1985 and is basically a test craft, but with cometary experiments added following weight problems with Planet-A, the main Japanese probe. Data from the two

The landing sites of Veneras 4-14 are shown, as well as the target landing site for the two Vegas.





The basic body of the Soviet Vega Venus/Halley's comet spacecraft. This is the section that will encounter Halley next March; the Venus landing capsule is housed in a spheroidal heatshield at top, although in the photograph it is not yet attached. The cylindrical section in the centre carries the propellant tanks; the scanning experiment platform has yet to be added to the bottom section. *Novosti*

Vega missions will be used to refine the trajectory requirements for Giotto so that the ESA probe can be accurately targeted.

The Vega Spacecraft

The spacecraft are modified versions of the second generation Venera craft. This is a two module vehicle: a large bus module carries the main propulsion system and the communications system, which links the lander and Earth, and a descent module.

The basic Venera bus has been only slightly modified for Vega [1]. An experiment platform has been added at the end of an arm at the base of the bus, this being dedicated to experiments for Comet Halley. A special magnetometer boom (length about 5 m) has been added and an extra set of solar panels is carried on either side of the vehicle. For protection at cometary encounter, extra shielding is carried against the expected cometary dust.

Equipment for the Halley experiments has been provided not only by the Soviet Union but also by Austria, Bulgaria, Hungary, the GDR, Poland, France, the FRG and Czechoslovakia. The Soviet Union, Bulgaria and France have built a spectrometer to make investigations in the ultraviolet, visible and infrared bands. An interplanetary plasma experiment was prepared by Hungary and the Soviet Union. Poland, Czechoslovakia and the Soviet Union co-operated on equipment to measure low-fre-

VEGA'S INTERNATIONAL COOPERATION

Signals from the Soviet Vega probes were received by a NASA tracking station for the first time on 21 January. As part of an international network organised by the French space agency, the 64 m antenna of NASA's Deep Space Network at Goldstone in California successfully received data from the two craft launched from the Soviet Union on 15 and 21 December.

Vegas 1 and 2 will each drop an instrumented balloon into the Venusian atmosphere in June to be tracked by two networks: the international system and an internal Soviet network.

Each Vega will also drop a lander to study atmospheric properties on descent. The gravitational field of Venus will then bend the Vega trajectories to place the remaining sections on a precise course for their March 1986 encounters with Halley's comet.

Once deposited in the planet's equatorial region, the two balloons will be free to float in the middle, most active, layer of Venus' three-tiered cloud system. Scientists hope that the data will help to further our understanding of the complex Venusian weather machine.

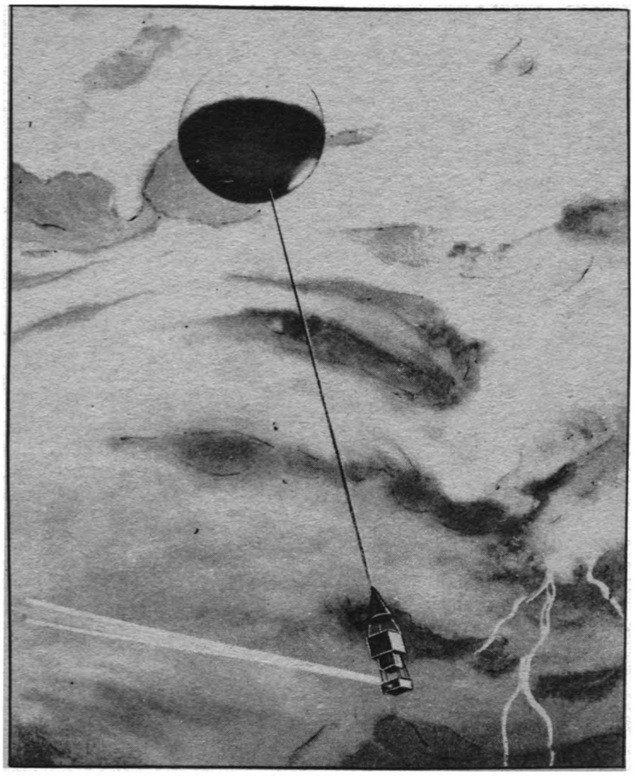
To track the balloons' movements, and thus measure wind velocity, transmitters will continually send signals to Earth during the two-day lifetime of each balloon. The signals will be received by three globally-spread hyper-sensitive 64 m dish antennae of NASA's Deep Space Network. Using the signals from the combined array of at least 10 antennae worldwide, in addition to data from the Soviet network, scientists will be able to calculate in detail the balloons' locations and motions using a radio astronomy technique known as Very Long Baseline Interferometry. It can measure balloon velocity, and hence Venusian wind velocity, with a precision of approximately 3 km/h at a distance of 108 million km from Earth.

The Deep Space Network antennae will make a unique contribution to the international tracking network in that they will also receive data from the other scientific instruments on the balloon gondolas. These include instruments to measure the frequency of lightning flashes, the vertical velocity of wind gusts, the temperature and pressure of the atmosphere and the location and density of clouds. One of the most important scientific objectives is to determine how these measurements vary with time and place.

Certain aspects of the atmospheric circulation of Venus are not well understood and scientists will be studying fluctuations in atmospheric phenomena such as wind and cloud cover density in order to learn more about the circulation. Understanding turbulence and wave-type motions in the clouds is important because Venus' cloud layers are believed to be the driving gear of the planet's multilayered weather machine. For example, scientists hope that data from the balloon mission will help to explain why the atmosphere at the cloud tops circles the planet once every four days, or at a speed of 400 km/h, as compared to near-calm at the surface of Venus.

Other atmospheric phenomena that are not fully understood include:

- how the massive, slow-moving lower atmosphere transfers energy and momentum to the relatively fast moving upper atmosphere;
- how the clouds evolve chemically;
- what chemical cycles are in force, i.e., how the sulphur source for the clouds' sulphuric acid is cycled up from the surface.



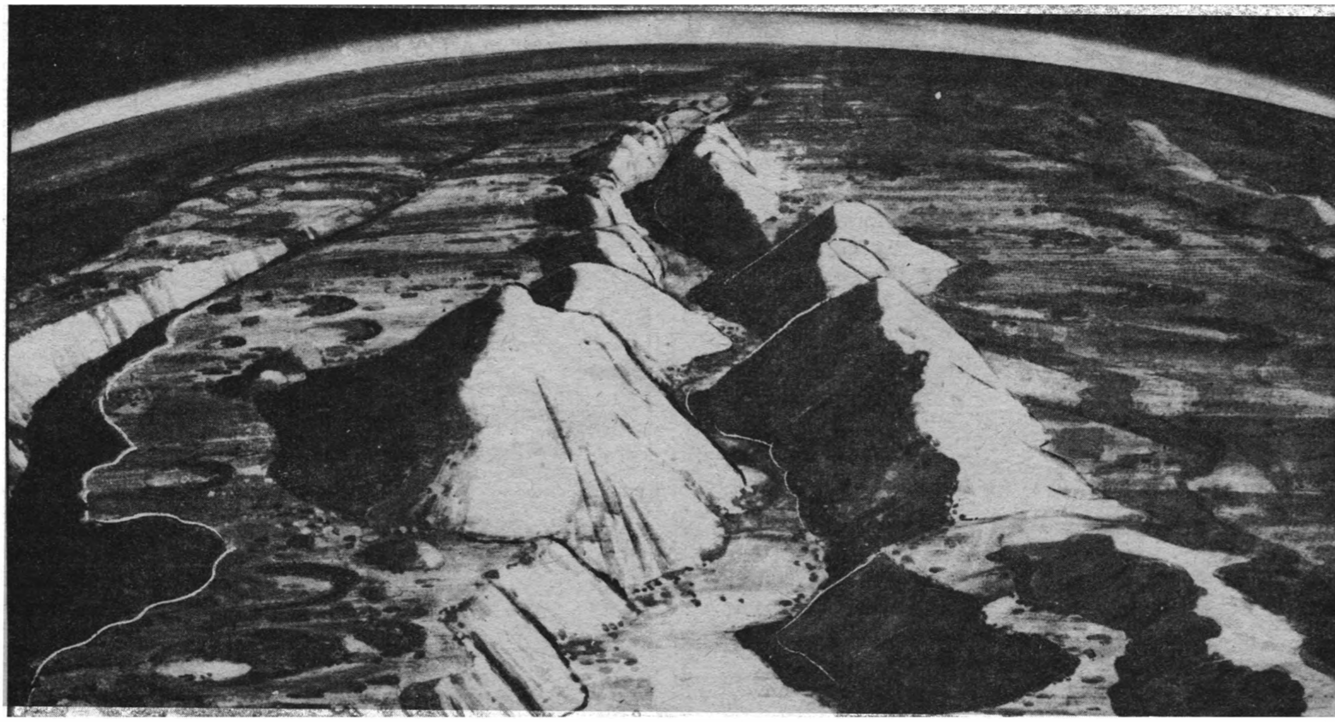
A Vega balloon floats in the atmosphere of Venus; an active cloud detector emits an infrared beam as other experiments study temperature, pressure and lightning. The US Deep Space Network will provide tracking support. *NASA/JPL*

In order to gather atmospheric data during the Venus encounter, each balloon will carry its scientific instruments housed in a narrow, segmented gondola about 1.5 m in length. The balloons themselves will be helium-filled and will measure about 3 m in diameter, with the gondola suspended about 12 m below.

The US science team has been working with French scientists of the Service d'Aeronomie of the Centre National de la Recherche Scientifique (CNRS), directed by Prof. Jacques Blamont, who was also the initiator of the balloon project. The data will be analysed jointly. US team member Boris Ragent of NASA's Ames Research Center provided the design of the nephelometer to measure cloud properties.

Although much is not understood about Venus' atmosphere, scientists do know some of the significant characteristics of the environment in which the balloons will float, from Pioneer Venus probe data and from early Soviet lander-probes. The middle cloud layer extends from 49 to 55.5 km above the surface, the temperature varying from 72 to 13°C. The pressure at the balloons' altitude is half an atmosphere - about a thousand times the pressure of Earth's atmosphere at the same altitude. As with all of Venus' cloud layers, the middle cloud layer is made up mostly of droplets of concentrated sulphuric acid.

The balloons' batteries will run out of power after 60 hours. However, after about two days the balloons will cross from the night side of Venus into the day side and it is likely that they will not survive the Sun's heat. They will probably become too hot, causing their internal pressures to rise and the fabric to burst.


An artist's impression of the large rift valley at the eastern end of Aphrodite Terra. *NASA*

quency wave oscillations in plasma around Halley. The science platform has a mass of 253 kg, of which experiments account for 85 kg; 20 experiments are being flown specifically for Comet Halley investigations.

The total mass of the fly-by bus, including fuel, is about 3,500 kg.

The Venus descent craft are based upon those of the Venera 9-14 missions of 1975-1982 [1] but there are differences. The descent section consists of three items: landing craft (675? kg), heat shield (750? kg) and balloon (115 kg). These figures give a total descent craft mass of 1,540 kg and a total spacecraft mass of 5,040 kg, in line with the figures implied from the energy requirements of the trans-Venus trajectory. The surface experiments have a mass of 117 kg.

The landers will be targeted towards an area not previously visited by Veneras: at about ±7° N, 180° longitude. Based upon previous missions, data should be returned *via* the fly-by bus for about two hours.

The new element in the descent complex is the inclusion of the helium-filled 'aerostat' balloon, with a diameter of 3.4 m and 4-5 kg of experiments.

Launch and Encounter

The launch of Vega 1 was at about 09.16 GMT on 15 December 1984 from the 'Baikonur' cosmodrome (actually near Tyuratam and Leninsk) using the Proton SL-12 booster. The pictures released were the first to show the full Proton vehicle. Vega 1 was placed into an initial 51.6,° 168-205 km parking orbit and, before the first orbit was completed, the Proton's escape stage ignited to take it out of Earth orbit into a heliocentric, trans-Venus orbit.

Vega 2's launch came at about 09.14 GMT on 21 December, with the vehicle entering an initial 51.6° orbit similar to that of its predecessor. The move into a heliocentric trajectory was successfully made about 70 minutes after launch.

Vega 1 will arrive at Venus on 14 June 1985, folllowed by Vega 2 four days later; it is hoped that the two descent craft will land 500-1,000 km apart.

The balloons will be deployed at an altitude of about 54 km and should operate for at least 24 hours, with their experiments studying cloud movements, atmospheric pressure and temperature and cloud particle characteristics.

The landers should survive on the surface for about two hours investigating surface temperature, atmospheric pressure, light scattering and absorption, and the chemical composition of the rocks.

Future Venus Launch Opportunities.

Launch	Arrival	Launch	Arrival
1988 Mar/Apr	1988 Jul	1989 Oct/Nov	1990 Feb/Mar
1991 Jun	1991 Oct	1993 Jan	1993 May
1994 Aug	1994 Dec	1996 Mar/Apr	1996 Jul
1997 Oct/Nov	1998 Feb/Mar	1999 Jun	1999 Oct

Launch opportunities occur about every 19 months, while the launch windows repeat after eight years (compare 1988 and 1996). These months assume that encounter with Venus is made before the probe has flown through 180° of its trans-Venus orbit.

Encounter with Halley

Vega 1 will be the first to encounter Comet Halley, passing through the tail some 10,000 km from the nucleus on 6 March 1986. Vega 2 should also pass through the tail, but this time at only about 3,000 km from the nucleus on 9 March 1986.

The experiment platforms will observe Halley during three main sessions: the first will be 14 million km before encounter, the second 7 million km away and the third starting 650,000 km before encounter. When encounter takes place, the relative velocity will be about 78 km/s.

Acknowledgements

The author would like to thank Novosti Press Agency for their help.

REFERENCE

1. P.S. Clark, 'The Soviet Venera Programme,' *JBIS*, **38**, 91-92 (1985).

SEEING COMET IRAS WITH A RADAR EYE

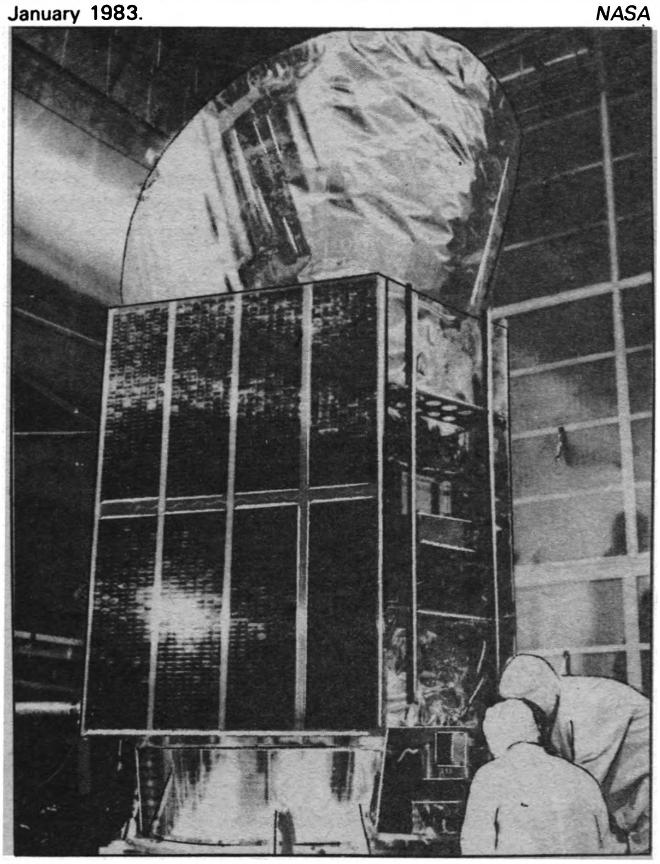
By Dr. Raymond F. Jurgens

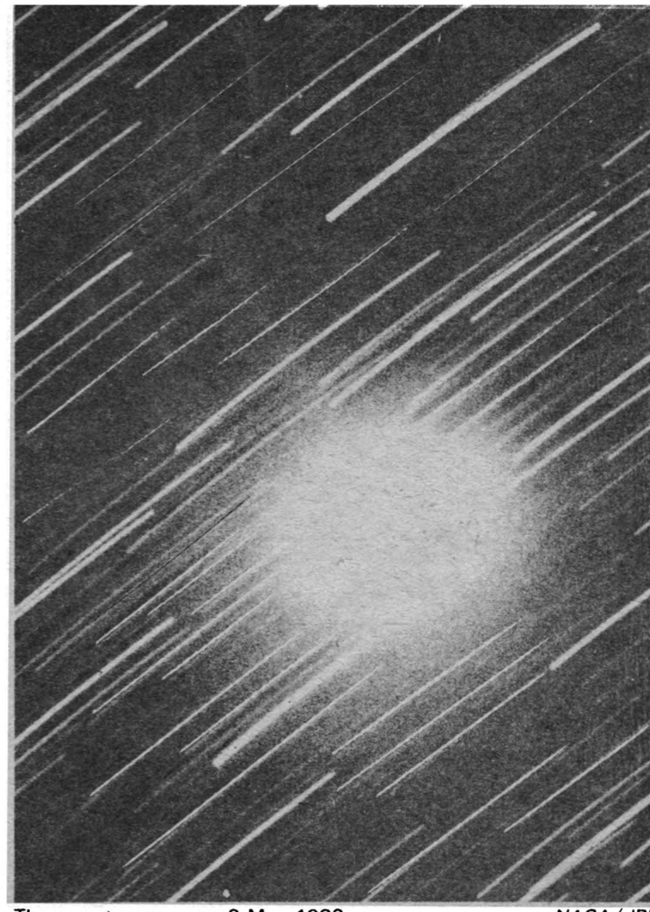
The discovery of Comet IRAS-Araki-Alcock by the Infrared Astronomical Satellite in April 1983 was an exciting event for astronomers. Not only could they bring the usual battery of scientific instruments to bear as it made its unusually close approach to Earth but a rare radar contact could be made. The author, who specialises in radar work at the Jet Propulsion Laboratory in California, describes the trials and tribulations - and eventual triumph - of the project.

Introduction

On 28 April 1983, Tom Chester, who was working on the IRAS project, told me of the discovery of an object thought to be an asteroid. For several days, the excitement began to build. By then, rumours that the object would approach close to the Earth were spreading around the Jet Propulsion Laboratory and people were beginning to talk seriously about observational programmes. Even if this were not a comet but just another asteroid, the distances being mentioned would surely make it the event of the decade. Distance is the most important parameter for radar detection, since the detectability depends upon its inverse fourth power (e.g. it is 16 times more difficult to detect at only *twice* the distance). However, this was a comet and it was coming closer to the Earth than any previous object in the brief history of radar astronomy (excepting the Moon and meteors). Comets P/d'Arrest, Kohoutek 1973 XII and Bradfield 1974 had been

The Infrared Astronomical Satellites (IRAS) is prepared for launch in January 1983. NASA



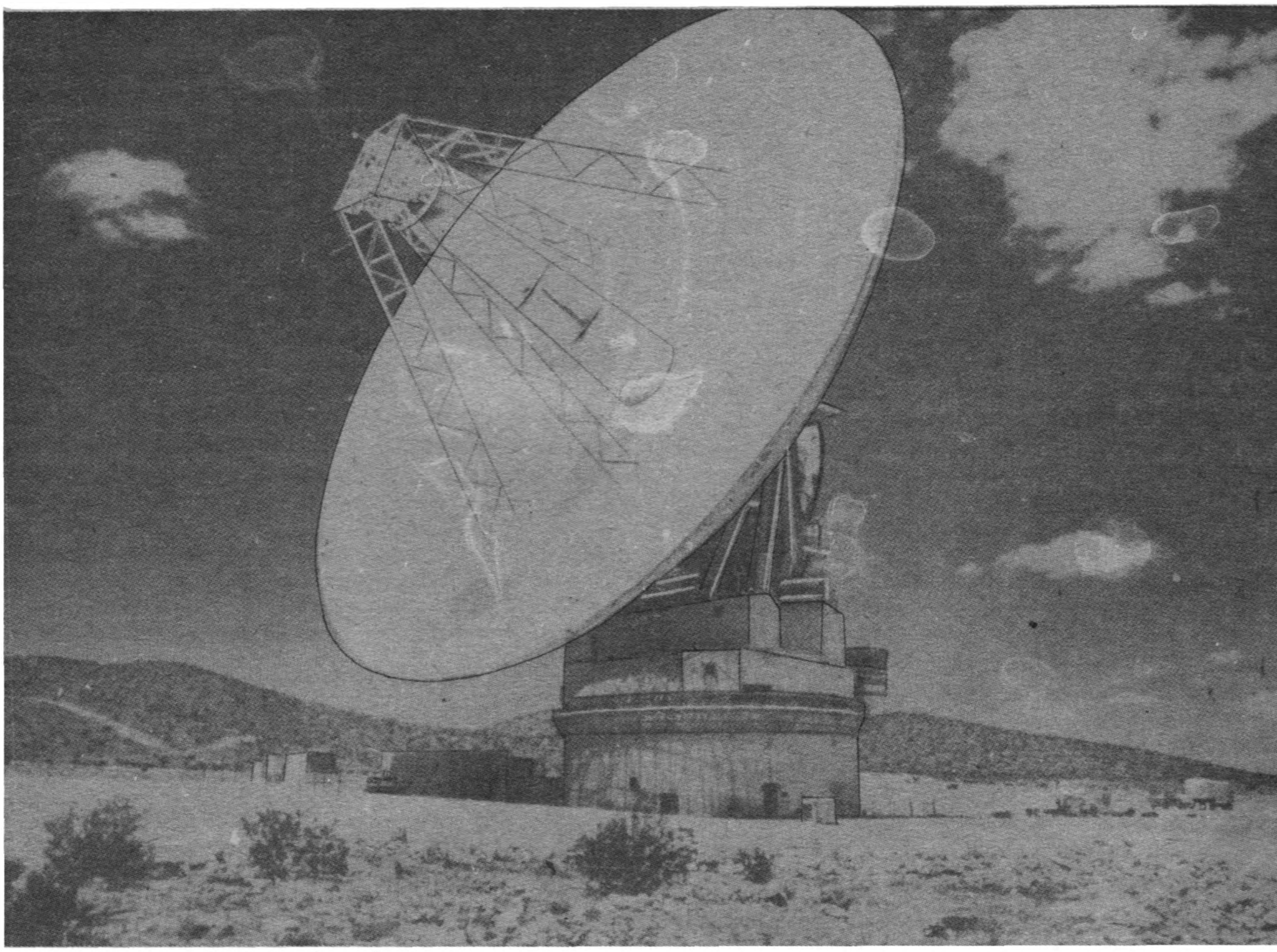


The comet as seen on 9 May 1983. NASA/JPL

attempted in the past, but with no detectable echo. Comet Encke had been detected by Kamoun *et al* in 1982 using the Arecibo Radar but its great distance yielded only a weak echo that restricted analyses to the most rudimentary types [1]. A weak detection of the Comet P/Grigg-Skjellerup was also reported by the Arecibo group but these echoes were tantalising at best [2]. Searches through the list of periodic comets revealed no good opportunities for the decade, including Comet Halley which would be at distances greater than 0.40 AU (60 million km). It appeared that we would have to wait a long time to study a comet in the same detail that we have studied asteroids during the past decade.

To get some idea of what we wanted, consider an object at a distance of 0.2 AU having a radius of 1 km, a radar albedo (reflectance) of at least 10% and spinning no faster than perhaps once in eight hours. The Goldstone radar system can transmit at 12.9 and 3.54 cm wavelengths (S-band and X-band respectively), with the X-band system being about four times more sensitive than the S-band. With X-band, such an object would yield a signal to noise ratio of only two to one after five hours of signal integration. Normally, a ratio of three is considered marginal for detection purposes. Other studies require larger ratios so that the temporal signature of the echo can be observed. Greater signal to noise ratios are obtained if the object is larger, if its surface is more reflective, if it spins more slowly (thus restricting its bandwidth to a narrower channel) or, best of all, if it is closer than this example. Of course, a bigger radar antenna, a more powerful transmitter and a more sensitive receiver system would help, but no new facilities have been built in recent years.

By 4 May 1983 it was clear that this comet would pass at a distance of 0.03 AU (450,000 km). Such a distance was beyond our greatest hope for a lifetime and,



The 64 m dish in the Mojave desert of California, or Deep Space Station #14 as it is more formally known. *JPL*

if this were not enough, a second comet had been discovered that would pass at twice this distance a month later. As luck would have it, the JPL radar system had been shut down following the unsuccessful tracks of asteroid 4 Vesta on 28 May 1982. Since the radar system had seen only sporadic usage over the past few years, the X-band transmitter, the 20 year old radar computer and the data acquisition equipment were unreliable. We were in the midst of a major rebuilding project that would not be put into operation until March 1985. Fortunately, we had not removed the old equipment. Carl Franck was sent to Goldstone to make an assessment of the problems. He returned with a list showing that the SDS 930 computer would run only at 18°C, the PDP 11/20 slave computer was not functioning, the digital sampler did not interface with the computer bus and the CSPI spectrum analyser was not functioning properly. One might have concluded that it was hopeless at this time, but Stan Brokl, Carl Franck and I set about the task of repairing the equipment with great confidence that it could be made to work. We alerted the observing crew of a possible radar track and began the scheduling procedure.

A Plan of Attack

Mike Keesey of JPL prepared a radar ephemeris for the comet from orbital elements supplied by Brian Marsden of the Smithsonian Astrophysical Observatory. This was updated as new optical observations were made. Nick Renzetti and Rick Shaffer of JPL began to look for observing time near the time of closest approach. This was no simple matter since many of the experiments using the 64 m antenna are scheduled years in advance. Unfortunately, a full week of VLBI experiments involving synchronised operation of many radio telescopes around the world was in progress. Following this, Gary Hiligman had scheduled a new experiment that had been waiting for telescope time for six months. Clearly, scheduling was going to be a most difficult task.

By the end of the week, we had obtained two four-hour tracking periods and had managed to get the SDS 930 computer and its low rate data acquisition system working. Our wide band spectrum analyser connected to the PDP 11/20 resisted our efforts. However, we were able to schedule the 65536 channel digital spectrum analyser used for RFI surveillance. George Downs was already trying to modify this machine to clock at slower rates to enable greater spectral resolution to be obtained. Richard Goldstein and I began working out the observing strategy.

The observing plan for such objects is normally influenced most by the uncertainty in the pointing ephemeris and the Doppler frequency prediction. Since the radar beam is 8.5 minutes of arc in width for the S-band system and only 2.3 minutes of arc for the X-band, we decided that the first observation must be at S-band. The first observation was also nearest the time of closest approach, where the extra sensitivity of the X-band system would not be required. We would observe using the RFI spectrum analyser in conjunction with the SDS computer. The RFI analyser could not resolve the cometary spectrum but was essential to cover the wide Doppler frequency uncertainty. The SDS data acquisition system would provide the necessary resolution to see the details of the spectrum. If we were successful with the S-band experiment, data on two wavelengths would result by

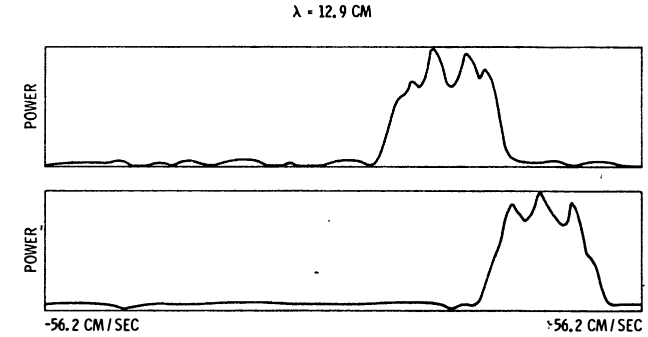
using the second observing period for X-band observations. By that time the distance to the comet would have increased and the echoes would be expected to be 23 times weaker. The added sensitivity of the X-band system would buy back only a factor of four, so the resulting spectra would be weaker.

The radar data would have maximum value if we could unravel the various physical parameters that are coupled together in the observables. The observables are the total echo energy returned in each of two orthogonal polarisations, the spectral bandwidth and shape and any distinct spectral feature. The desired physical parameters are the roughness and scattering mechanism of the surface material, the dielectric constant of the surface material, the rotation period, the direction of the spin axis, and the size and shape of the object. Only in the case of the asteroid 433 Eros have we ever unravelled all of these and then only with the help of certain optical observations [3]. In the case of a comet, the nucleus might be obscured by dust and optical measurements of the size might not be possible. In fact, the size might be the most important piece of information. In one case it is coupled with the surface albedo to give the reflected energy and in the other it is coupled with the rotation period and the direction of the spin axis to give the spectral bandwidth. That is, the Doppler spread from limb to limb depends upon only the velocities along the line of sight. Thus, the spectral width depends upon the direction of pole relative to the observer, the rotation period and the maximum visible width either side of the projection of the pole on the celestial sphere. If the pole were directed toward us, the spectrum would have zero width. Fortunately, the temporal variations of these observables often aid the process of separation, especially if several complete rotations can be viewed and the angle of viewing varies (i.e., the object moves significantly in the sky) [4].

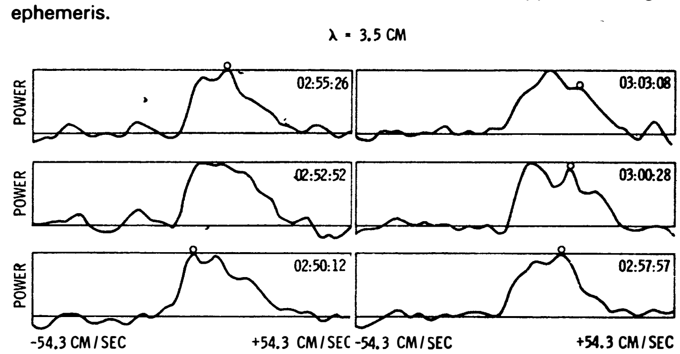
Observations

Our first observation was on 11 May 1983. Our crew was still trying to repair several instruments. We had injected test signals into the receivers to verify that they worked. There were the usual delays caused by the paper tape reader that stubbornly refused to read the Doppler predict that steered the programmable local oscillator. Finally everything was ready. The round trip time for the radar echo was only 33 seconds. The sequence of events had to go like clockwork. Each action had to be verified to be sure that all the switches were in the proper position for each cycle. First the antenna was pointed ahead of the comet and the transmitter brought up to 400 kW. When the intervening space was filled with one long echo, the transmitter was turned off, the antenna was repointed to the apparent position of the comet and the receiver turned on. Out of every 33 seconds, only about 15 to 20 seconds of signal was recorded. Our oscilloscope display indicated the spectrum and, on the first cycle, a small blip was noted to the far right side. We were uncertain as to whether the blip was at the frequency indicated or an alias of our sampling frequency, but the RFI analyser was able to see the signal. From its frequency measurement, we were able to centre the blip on our display by shifting the transmitter frequency. We then began the process of increasing the resolution. After several cycles, we noticed that the frequency was not stable and that we would have to chase the echo manually as it drifted across the display. We also observed that the spectrum was relatively flat and that its shape was much like that observed from small asteroids.

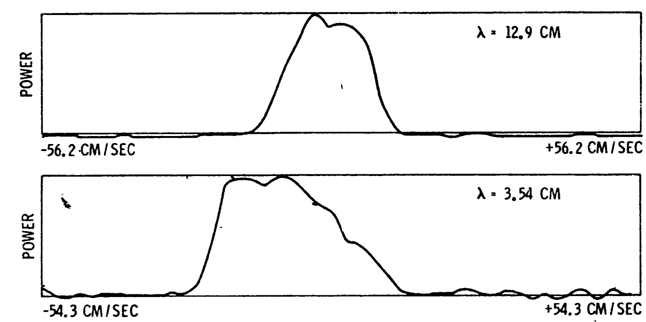
A number of people had collected in the room to look at the spectra and we had not noticed that the room had become comfortably warm. Just as we were about to



Consecutive S-band spectra that have been smoothed (to reduce speckle noise), showing possible features. The displacement is due to errors in the orbit that was used to calculate the Doppler tracking ephemeris.



A sequence of consecutive X-band spectra that have been smoothed showing spectral shape and motion of a possible feature (shown as a circle). The positions shown would require a rapid rotation rate. The spectra are both wider and stronger than those from the S-band.



Average of all power spectra for S-band (11 May 1983) and X-band (11 May 1983) observations as a function of radial velocity in cm/sec showing the average spectral shapes. The S-band (upper) is almost parabolic; X-band (lower) is more wedge-shaped.

measure the opposite circular polarisation, the computer failed. Several attempts to reload the data acquisition program were unsuccessful. Then someone noticed that the room had reached 24 °C. For the next hour we began an intensive effort to cool the room. Finally we were able to record data again, but the end of the track was only 15 minutes away. No depolarised spectra had been recorded and the nature of the scattering mechanism would be uncertain until the next track.

In planning for the next track, we observed that the signal was stronger than we had anticipated and that we would have no trouble observing on the next track if the antenna pointing prediction was good enough. We also knew that it was essential to measure the depolarised echo spectrum to understand the nature of the scattering. If the surface were composed of fractured ice layers like Callisto (a major moon of Jupiter), it would be highly reflective and would strongly depolarise the radar wave. If the surface reflected by simple Fresnel scattering from facets, the reflectivity would be low and there would be little depolarisation. The new wavelength would provide new data on the scale size of the roughness and presum-

ably the Arecibo radar would have good data at S-band. Clearly, we had to risk the possibility of no echo due to the uncertainty in the antenna pointing predict and try for the shorter wavelength.

Our next observation was on 14 May 1984 and again we made a massive attempt to get the wide band spectrum analyser working. Again we failed, so the mode of observation was to be the same as before. This time we were able to keep the room cool and the computer functioned properly throughout the track. Our first cycle revealed an echo so we increased our resolution until the spectral width was revealed, somewhat wider than we had expected. After several cycles, we shifted the polarisation and observed that the power returned was about four times smaller than for the polarised or proper mode of reflection. Clearly we were seeing the reflections primarily from a very rough faceted surface. This measurement would figure most importantly in the subsequent months of processing and analysis that followed.

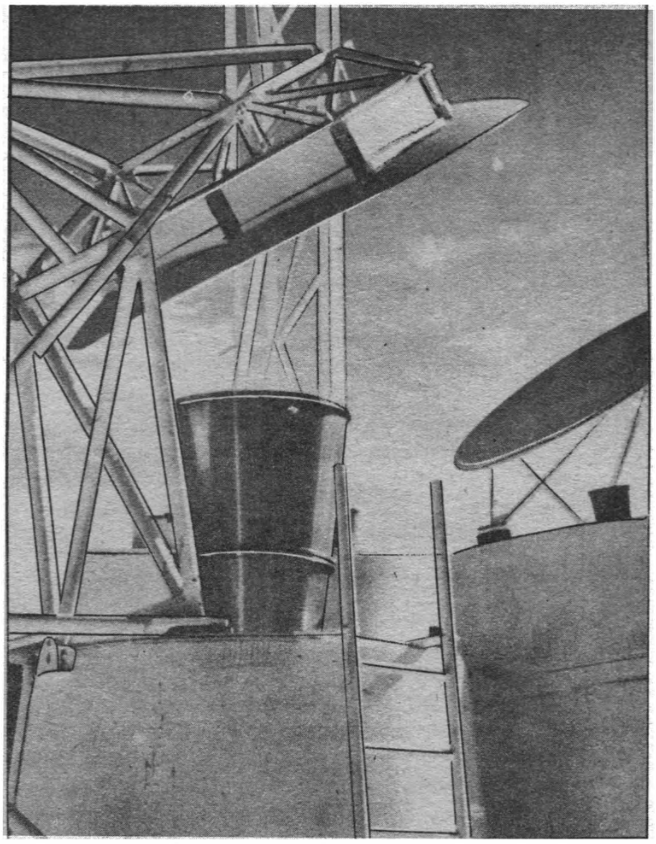
Analysis

The data processing and analysis project was lead by Richard Goldstein and Zdenek Sekanina. There were many puzzling problems with the data. The X-band cross section was two times larger than the S-band, the small features appeared to move too fast, indicating a preposterous rotation rate of 1.6 hours. This would indicate a radius of a few hundred metres, in conflict with the large cross section. We considered many complicated models based on scattering from rings and clouds of particles to explain these strange measurements but in the end these could not be justified on theoretical grounds.

We carefully smoothed the data to reduce the speckle noise generated by the scattering from random facets in order to observe the average shape of the spectra more clearly. This revealed that the average shape did not change appreciably during the span of the observations. We had observed similar spectra from 433 Eros as it rotated [3]. The spectral shapes are formed by a combination of the geometrical shape and scattering properties. The theorectical cases studied were for triaxial ellipsoids having roughly Lambertian scattering properties. Although many other models would be consistant with the observations, this one does agree well with the measured spectra and gives radii in agreement with other observations. Specifically, we conclude that the comet is irregular in shape. Its equatorial radii are roughly two to one in length and the size of the largest radius is 6 km if the spin period is two days. The size could be proportionately smaller if the period is shorter. We also believe that neither observation was made near the polar axis as this would have surely revealed a change in spectral width over the duration of the runs. The rotation period must be greater than one day and probably near two days in order to bring the surface albedo into agreement with those of the surfaces of small asteroids that have similar reflection properties. Initially unnoticed was a wide band spectral component that is asymmetrically distributed either side of the nuclear component. This scattering apparently results from the reflection of waves from cm-size particles gravitationally unbound to the comet. These particles apparently fill the entire radar beam and have a cross section of roughly 25% of the that of the nucleus. The details of these analysis are in Ref. 5.

Future Prospects

One month later we were ready and waiting for the comet Sugano-Saizusa-Fujikawa. We had scheduled four full days of observation and delayed the renovation of the 64 m antenna for one month. Night after night we searched the sky in the area of the comet with no indication of an echo. We can only conclude that comets vary greatly. To know how different may take great patience and several centuries unless the discovery rate of close approaching comets increases markedly or larger radar systems are built.



A close up view of the tri-cone feed horn on the 64 m dish. The larger horn supports the high-power S-band system, while the X-band cone is at right. *JPL*

Acknowledgements

We wish to thank our Goldstone observing crew for completing many hours of arduous transmit-receive cycles and on-the-spot instrument repairs, the many observers who contributed optical plates, Brian Marsden, who coordinated the development of the orbital elements and the many others who participated in scheduling and preliminary arrangements for facilities and staff. The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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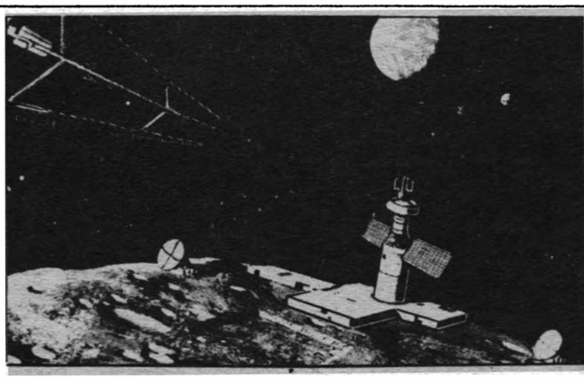

The first of this year's *Space Education* issues includes a range of articles on astronautics and astronomy. Two cover infrared and X-ray astronomy from above the atmosphere, emphasising the enormous strides achieved since the beginning of the Space Age. The Voyager encounter with Neptune in August 1989, which will revolutionise our knowledge about the planet, is reviewed in a NASA/JPL article. Robert Frisbee contributes the first part of a comprehensive basic survey of rocket propulsion systems while Robert Mackenzie completes his description of an exciting branch of astronomy with 'Meteor Astronomy: Comets, Minor Planets and Meteor Streams.'

Tom Patrick, of the Mullard Space Science Laboratory, provides an insight into the structural design of satellites, and Robert Christy, who contributes the regular 'Satellite Digest' to *Spaceflight,* considers the geostationary orbit in 'An Orbital Guide.' Roger Smith discusses the use of Landsat imagery in the teaching of geography and Paul Maley describes how to employ video techniques in amateur astronomy.

Copies of the May *Space Education* can be ordered for just £2 ($4) each, post free.

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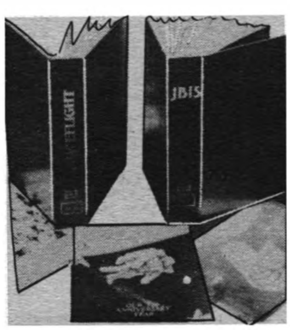

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JBIS

The May issue of the Journal is devoted to 'Solar System Exploration' with the following papers:

1. 'Far Eastern Observations of Halley's Comet: 240 BC to AD 1368,' by Dr. F. R. Stephenson and K. C. Yau;
2. 'Exploration of Planetary Atmospheres,' by Dr. G. Hunt;
3. 'The Giotto Spacecraft Configuration and its Achievements,' by D. C. Clayton and P. Truss;
4. 'Comet Coma Sample Return *via* Giotto II,' by P. Tsou, D. E. Brownlee and A. L. Albee.

This *JBIS* issue is available at a cost of £2 ($4) per copy post from The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

The April issue of the Journal is devoted to 'Astronautics History' under the editorship of space historian Mitchell Sharpe. The following papers are included:

1. 'The Rocket as Spacecraft: Spent Stages in Manned Space Flight,' by W.D. Compton;
2. 'Pioneering Commercial Rocketry in the United States,' by F.H. Winter and F.I. Ordway;
3. 'A Study of Early Korean Rockets (1377-1600),' by Y.S. Chae;
4. 'A History of Inertial Guidance,' by F.K. Mueller.

IN RETROSPECT

In November 1983 participants in the old British 'Black Knight' rocket campaign met on the Isle of Wight to celebrate the 25th Anniversary of their first, successful, launch. Among them was BIS Fellow Charles Tharratt, who participated in the project as Chief Rocket Development Engineer.

Black Knight has usually been relegated to the position of a footnote in the pages of space history but, as Mr. Tharratt relates below, it was an important development in its own right.

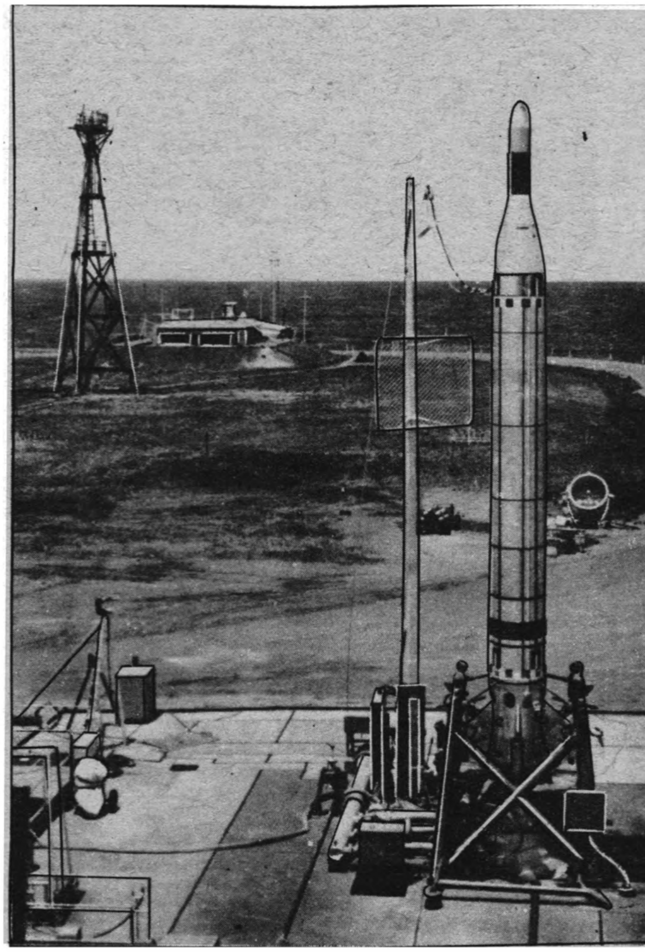
While others involved in the Black Knight project might have differing viewpoints and memories to mine, we share a common bond.

In September 1958 the simple rocket concept called Black Knight climbed the near-vertical beam of an old 584 radar as two ground-based pilots issued pitch and yaw commands to steer it along the electrical centreline of the radar beam. Following engine cut-off, which came a few seconds earlier than planned for that first launch (BK-01, as it was called) soared in a ballistic trajectory to an apogee of over 564 km above the Australian desert. Thus, the world altitude record to apogee, previously held by the four-stage US Aerobee, was comfortably broken by a single-stage BK-01. That event should have been acknowledged by a place in the record books but, reviewing any encyclopedia of space achievements, there is a high probability that Black Knight is not even mentioned. One explanation is that, due to a delayed schedule, the achievement was totally overshadowed by the earlier orbital launch of Sputnik 1.

A delayed schedule suggests many things but the root cause was a shoe-string budget. The difference between the efforts put into Blue Streak and Black Knight was as stark as the difference between a Rolls-Royce and a Model T Ford, although both performed the same function.

I recall a group of US Air Force officers touring the Black Knight test facility at High Down on the Isle of Wight. A Colonel came into the office with a puzzled expression, 'Where is everyone?' he enquired. Having been assured that he had met everyone, the good Colonel confessed that he could not believe that such a small group had assembled and activated a site of that nature and purpose in such a short time - one year from cutting first sod to first prototype static firing. The activity on the site, and the fact that pleasure boats around the Needles could witness the progress of construction work on two gantries atop of the cliffs, triggered a rumour among Isle of Wight residents that there were two launch pads, one aimed at Moscow and the other at Washington! Nothing was further from the truth, of course, but there is no accounting for imagination. The secret of such progress, if there ever was one, was due to the fact that all personnel whether engineers, technicians or clerical, were classified as 'staff,' which avoided the costly effect of union demarcation practices. As a consequence, everyone assisted everyone else. For instance, each engineer (from Supervisor down) knew where every cable was, which distribution boxes they went to and which instruments or equipment they operated.

They knew because, at one time or another, every propulsion, instrumentation, mechanical, electrical or control engineer had assisted in the pulling or laying of those cables and the hook-up and checkout of associated equipment. When one does that atop a 150 m Down, overlooking the English Channel, with 100 m sheer chalk cliffs on two sides, in 30 cm of snow and with an 150 km/h gale blowing, one remembers it well!

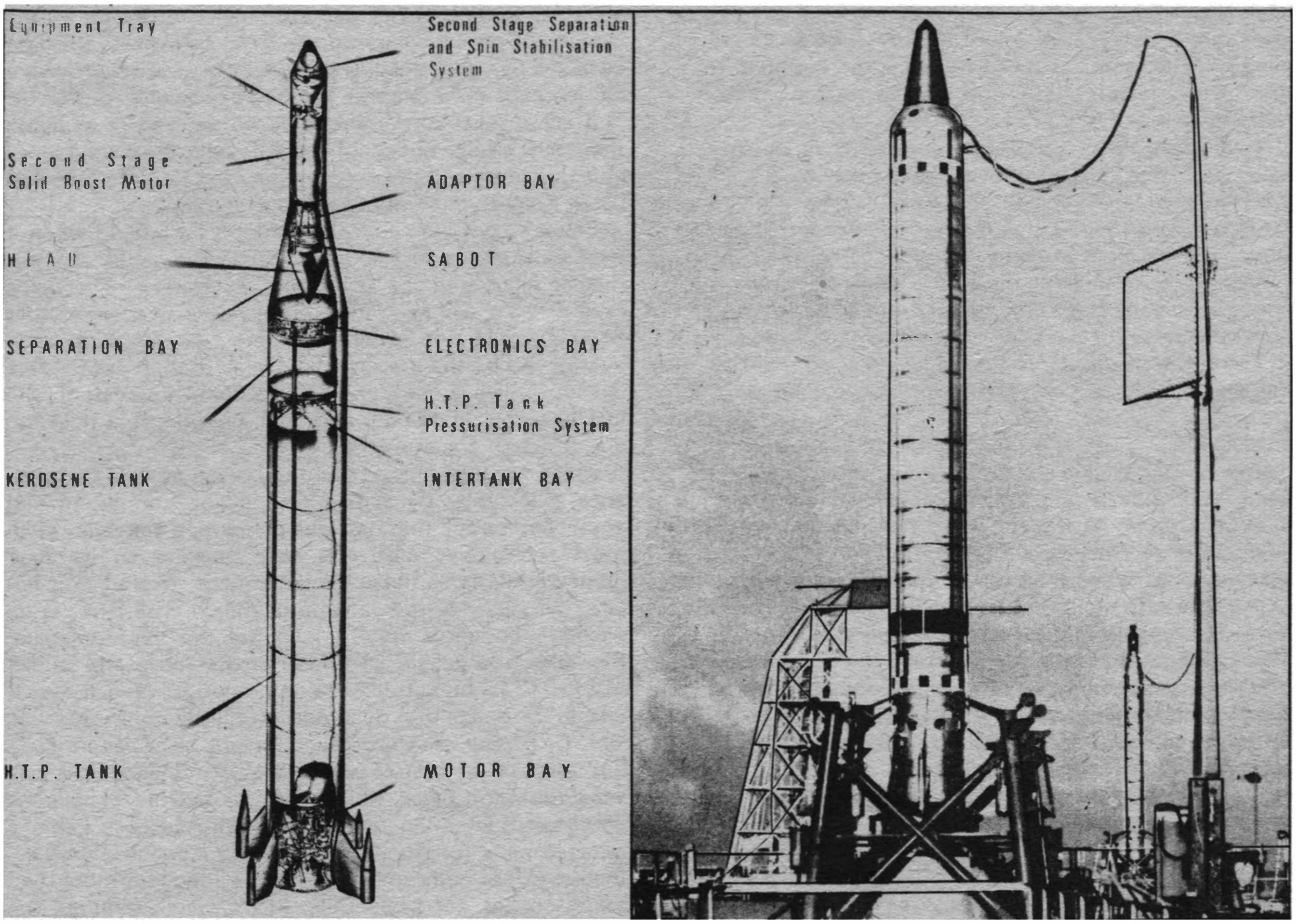


A Black Knight on the launch pad at Woomera in Australia. Black Arrow was also fired from here. *RAE*

Even so, High Down was an island paradise compared to Spadeadam in winter. On one occasion a senior engineer complained that his clothes were getting wet as he calibrated the water flow from an overhead storage tank while using a makeshift stop valve. He was in a mess, so I recommended that he should remove his clothes. He did and, naked, satisfactorily completed the tests. Needless to say his reward was a generous tot of rum. The important point is that the job could not have been accomplished within cost and schedule if job demarcation had been necessary. It should not be construed as a one organisation effort; it was not. Anyone associated with the project, government scientists (they were most helpful), support contractors and personnel from a variety of organisations was pressed into service. Strangely enough, they did it willingly. Consequently, one of the greatest achievements of the programme was the magnificent cooperation between many organisations who subordinated their diverse objectives and goals to a secondary role.

Experience gained under these conditions handsomely paid off because, whenever a problem occurred, as frequently happens during an early development period, discussions with one's colleagues on the problem were between equals who would invariably volunteer to assist in the search for a solution. If the Black Knight experience taught me anything it was to appreciate the power of a small team of engineers dedicated to a common goal.

Some years later, as a new member of the Chrysler Corporation Space Division (now defunct), I walked into the Engineering Department and gazed in amazement at



left: The Black Knight with a second stage used for driving a missile head down into the atmosphere at high speed. *Right:* the Black Knight in the background illustrates the downward-pointing second stage. *RAE*

the hundreds of engineers in that vast office within the NASA George C. Marshall Michoud Assembly Facility, in New Orleans. 'What does everyone do?' I asked of my American companion 'Beats me' he replied, with a characteristic shrug. It was then that I understood the perplexity of that Air Force Colonel, but in a reverse sense!

The central issue to the paucity of documentation about the programme is (or was) probably the result of the unusual organisation imposed upon the project. I do not believe that the organisation occurred by design. It probably just happened, in a uniquely British fashion, but one result has been a fragmentation of activities that few can link together to form a cohesive, continuous story.

Black Knight was a Royal Aircraft Establishment project. It was conceived as a low-cost method to obtain certain important reentry data necessary to complete the design of Blue Streak warheads. It was to be propelled by a cluster of four Gamma Engines (high test peroxide and kerosene) designed and developed into a highly successful engine, by the old, and illustrious, Armstrong Siddeley Engine Co., Ltd., from a design by RPE-Westcott who based it upon German wartime work. In that one long sentence one will recognise the emergence of a fascinating story all of itself.

The former Saunders-Roe Ltd., (later merged with Westland Aircraft Ltd.,) headed by Mr. M.J. Brennan (Chief Designer), were given the task of prime contractor. They designed, manufactured and developed the launch vehicle, test methods and procedures, the vehicle's test systems and the facilities. They installed a test facility at High Down on the Isle of Wight and another at Woomera, S. Australia. Everything had to be shipped to Australia; even the mobile gantries were manufactured in the UK, assembled and checked for operation in the UK, then disassembled and shipped to Australia where they were reassembled at the Woomera Test Range. There is another story all to itself, about the shipping of equipment, vehicles and personnel. In 1957/58 flying to Australia by DC-3 or, by the finest in the world (at that time), the Comets of RAF Transport Command, was a grand adventure.

Although Saunders-Roe had the task of ensuring the launch system worked, the more glamourous task of launch was given to de Havilland! This arrangement came about through a desire by the Government to ensure that de Havilland engineers of the Blue Streak trials team received launch experience prior to the launch of that larger rocket. Thus Saunders-Roe provided a team of five senior engineers with each launch vehicle and, with the support of an engine specialist from Armstrong-Siddeley, their rôle was to supervise the preparation for launch by de Havilland trials engineers. I led the first Saunders-Roe team.

Black Knight was launched at the Woomera Test Range operated by the Australian Weapons Research Establishment (WRE). The range, at that time, funded in part by the UK, was quite an enterprise and no account of Black Knight should overlook WRE's role in the project. Our fortunes in Australia revolved around the WRE, RAE and the UK Defence Mission in Melbourne.

Because the prime objective of each launch was to obtain re-entry information, some data were stored on magnetic tape within the payload, or head. The recorder therefore had to withstand the environment of re-entry and the deceleration of impact, and to operate satisfactorily after recovery (some vehicles carried a propulsive

payload; the solid rocket motor was fired several seconds after apogee to increase velocity of re-entry). The location of the point of impact was planned to be obtained from radar tracking data, with more precise data from Baker-Nunn cameras.

Those Baker-Nunn cameras were used to obtain the locus of a trajectory by photographing light flashes from a strobe at the base of one of the two fin-mounted pods. To be successful with this method, it was necessary to launch Black Knight at night during a period when moonlight was at a minimum. In practice, the radar and photographic methods proved to be too cumbersome and time-consuming to suit the recovery team who were eager to set out early the next morning. Looking for a hole in the desert can be a most frustrating occupation if its position is not previously known with a modicum of precision. To speed the process on later launches three teams were positioned in the desert prior to a launch. Being equi-spaced and at the same distance from the theoretical point of impact, their task was to note the direction of re-entry and to set out in that direction the next morning. When their tracks intersected, there would be the hole with the payload some 6 m below the surface. But it was not as simple as that, it still took a couple of days to locate the head. At this stage the Chief Recovery Officer, an ex-Londoner with a most wonderful sense of humour, hit on what was, to him, the obvious solution. He reasoned that, because the probability of Black Knight achieving a perfect trajectory was nil, he would take up position at the theoretical point of impact. This would ensure an opportunity to locate the payload before anyone else - a case of one-upmanship in its grandest sense because no-one volunteered to join him. His story, after his one and only experiment, remained atop the local hit-parade for months to come. On the moonless night, alone in the desert, the Recovery Officer sat at the theoretical point of impact awaiting the launch some 80 km to the South. He saw, in succession, Black Knight propelling along its ascent trajectory, then blackness punctuated only by the stars and brighter strobe flashes, then the spectacular flare of re-entry that appeared to be directly above. As he told it, the noise, like that of an on-rushing train, grew to a screaming crescendo as he dived beneath his nearby Land Rover for protection. The launch vehicle broke-up but solid parts did not burn-up as they traversed a near perfect trajectory (those guidance pilots did a grand job that night).

So with payload, individual Gamma engines, and an assortment of solid chunks of metal and equipment straddling, but not striking, the Land Rover with the bone-jarring thuds of impact the intrepid Recovery Officer beneath the Land Rover reasoned that this was 'a bl—dy stupid place to be!

Survivability through re-entry produced curious results. Following one launch a telemetry transmitter was retrieved from the desert after a fall of approximately 800 km. It was bent and battered but, after a cursory dusting and connection to power supplies, to everyone's amazement and delight, it still worked! Everyone, that is, except the Principal Scientific Officer whose only comment was 'it is clearly overdesigned and overweight!'

Nowadays, we are all familiar with the impressive sight of the Space Shuttle at lift-off but those, such as myself, who were privileged to witness the re-entry of Black Knight over 26 years ago can attest to the equally spectacular scene as the propellant tanks disintegrated over the Australian Donga (desert). This enormous brilliant white, green streaked, flare seemed to light up the desert for miles around.

Each launch vehicle had a specific payload developed by the RAE. The lessons learned from those payloads were fascinating but I have not seen any results as the data went straight back to the RAE. Likewise with data obtained by various Universities, whose experiments were carried aloft on a 'surplus payload availability' basis.

If some reliable method could be devised to evaluate the cost effectiveness of launch vehicles in terms of knowledge gained per programme cost I am certain that Black Knight would appear among the leaders.

Black Knight was conceived during the period when it was considered good sport to jest at the series of spectacular failures in the US space programme. The Black Knight team did not laugh. They were concerned that BK-01 should not suffer the same fate. A point often overlooked by the press and public is that an expendable launch vehicle is never tested as a complete system until it is released on its one, and only, mission. It is then too late to make adjustments.

In the 1950's engineers had to predict system performance aided only by slide rules, analog computers and digital computers that had less computing capability than most schoolboys and girls now possess to do their homework! Under these circumstances, overcoming failures was part of the scheme of things. The RAE, in its wisdom, budgeted for 12 launches per year. Imagine, therefore, the delight and pride at the successful launch of BK-01. To be sure it was not a perfect launch, but it *was* in the sense that no important mission objective was lost. Of course, that first launch might have been a fluke but, after similar results with subsequent launches, it was accepted that Black Knight was a reliable vehicle. A paradoxical situation then arose. With success came a reduced need for launch vehicles and launches. Besides, there was not sufficient variety of payloads for more than four launches per year. Thus, Black Knight suffered the same problem later to be encountered by the Saturn rockets of the Apollo programme.

For a brief period, Black Knight was considered as a second stage to Blue Streak to produce the 'Black Prince' satellite launcher, but that scheme died when Blue Streak was used by ELDO. In its final stage of life Black Knight became a stepping stone to Black Arrow, which demonstrated that high technology in materials, propellants, engines and electronics are not pre-requisites to lofting payloads into orbit, although they greatly help.

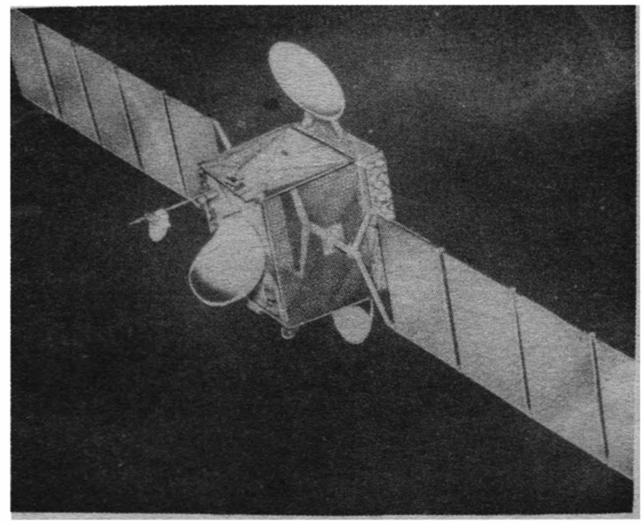
I feel sure that I speak for most, if not all, members of the Society, and for many fellow engineers, scientists and lay persons when I express a sadness of the unwillingness of Britain to grasp the nettle of space, of the wait-and-see policy of moguls of industry instead of leading the way into developing methods to manufacture rare products in space. Some, perhaps, hang back because they observe the cost of the successful US Space Programme and believe that they must pay the same price. They do not. Professor Tyzard was once asked how the UK could compete against the industrial strength of the US. His reply is as apt today as it was then, 'We shall just have to think a bit harder' he said. The concept of Black Knight had a simplicity that attained Professor Tyzard's standard. The idea stemmed from a government establishment, the RAE. Saunders-Roe applied standard aircraft practice to its construction and Armstrong Siddeley built an engine so workmanlike that it even had a polished manufacturers brass plate attached. The lesson and success of Black Knight can be repeated in today's environment if we return to basics. It is at times such as today that we continue to lament the passing of our old White Knight, Val Cleaver; we need the like of him to champion the cause and reveal the next leader.

We hope to include further contributions under the 'In Retrospect' heading. Participants in past space projects who would like to contribute should contact the Executive Secretary.

THE BIG COMMUNICATORS

By Larry Blonstein

Much has been written about the space stations of the 21st century. Design work is proceeding now, with many large aerospace corporations in the Western World collaborating closely on the concepts that will be employed in these massive structures of the year 2000 and beyond. They may be used for a variety of purposes but one is certain: handling the ever-increasing demands of world communications. The author, of the British Aerospace Space & Communications Division, discussed possible concepts for the future at the Society's Space '84 conference.



Unisat: an example of the British Aerospace Eurostar class. It is 3-axis stabilised with a DC power of up to 3 kW.

Introduction

Telecommunications spacecraft in orbit today generate a maximum DC power of about 3 kW and offer a capacity of around 50 low-power transponders. That means a traffic capacity of 25,000 two-way voice circuits or their equivalents in video and data, using Earth stations of typically 3 m diameter. The designers of the 21st century space stations are working on demands of millions of circuits through one orbital slot with stations developing DC powers of hundreds of kilowatts.

We know that jumping from 3 kW to hundreds of kilowatts in one step is not realistic. Technology does not work that way. Our next step from the 3 kW range is the 8 kW Olumpus class of communications satellites, the first of which is now under construction at British Aerospace and its collaborating companies in Europe and Canada. What next?

At British Aerospace, we have been closely watching the increases in traffic that are occurring through space systems and terrestrial systems; the patterns of that traffic within nations and regions and across oceans; the jostling for locations in the geostationary arc; the battle between the protagonists of high power and low power for direct TV broadcasting; the rapid developments in Earth stations technologies and the associated reductions in costs; the plans of the launch vehicle makers (including our own), and the many political, commercial and financial factors that affect the adoption and usage of space systems. At the same time, we are proceeding along lines of development in the design and construction of spacecraft with the continuous aim of higher efficiency at lower cost.

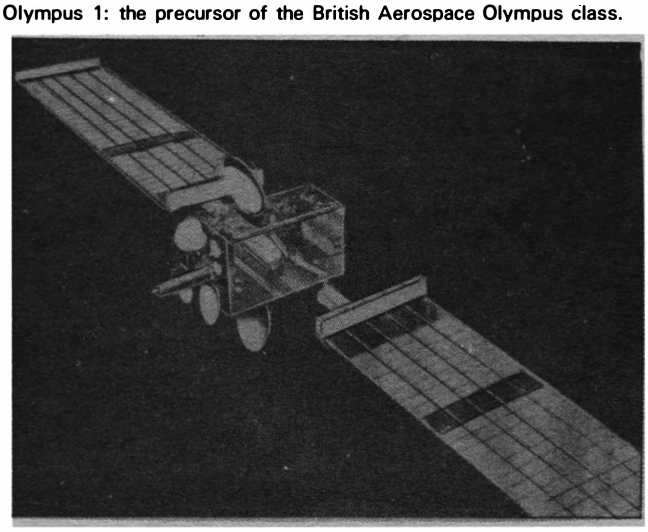
All this has led us to conclusions on what we should expect to see in orbit before the end of this century - between the eventual decline of the Olympus class and the start-up of the first space stations. We have developed a series of concepts for communications satellites of the 1990's that will exploit new (and old) technologies to the full, while avoiding the need for space station-type assembly in orbit. They will be launched as single payloads on Ariane or Shuttle or their equivalents of the day, and we are calling them the 'Big Communicators.'

The Big Communicators

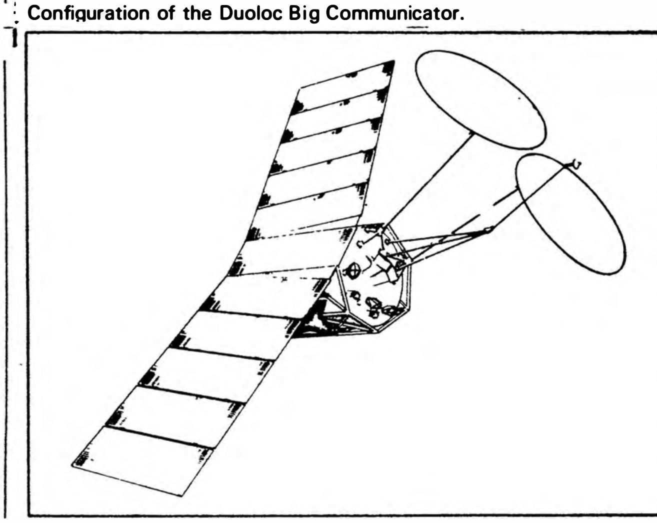
Today's communications satellites come in two forms: the spinner, exemplified by the Huges Aircraft series of satellites for Intelsat and other users, and the 3-axis stabilised, such as the Eurostar and Olympus classes.

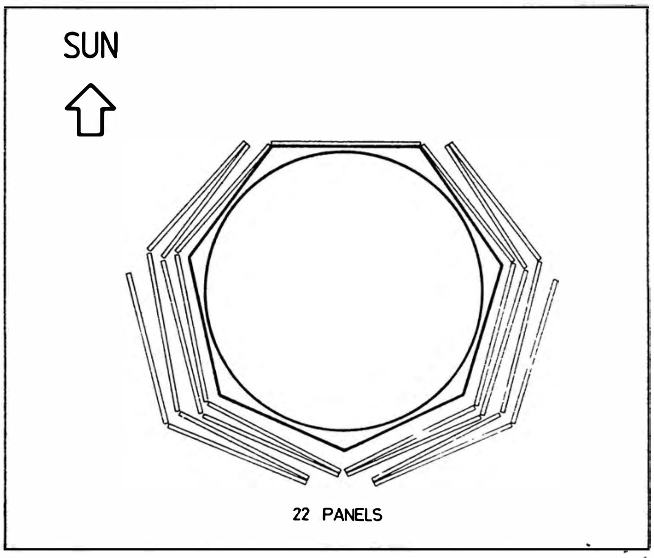
Within the confines of the Shuttle and Ariane launchers, which provide a payload envelope of about 4.5 m diameter, the spinner exhibits a limitation in DC power input of about 4 kW because of the limitation in solar cell collecting area on its body. Further, even with extensions in axial length that can be applied after deployment from its launcher to provide more power, the spinner suffers another limitation in its ability to dissipate waste heat into space. The waste heat from the internal payload and

Olympus 1: the precursor of the British Aerospace Olympus class.

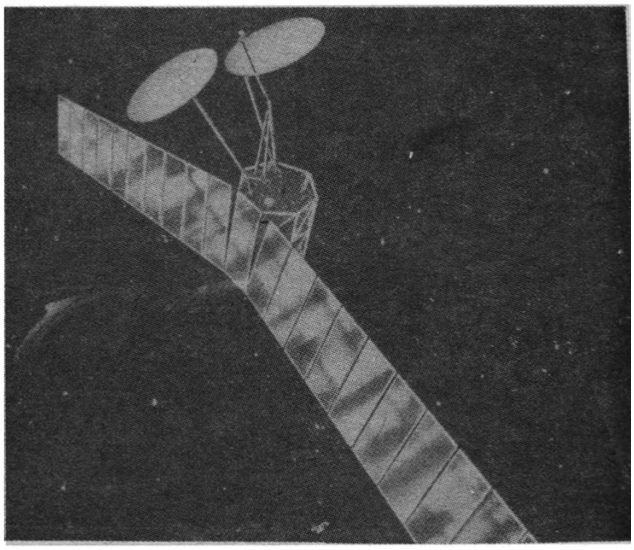


Configuration of the Duoloc Big Communicator.

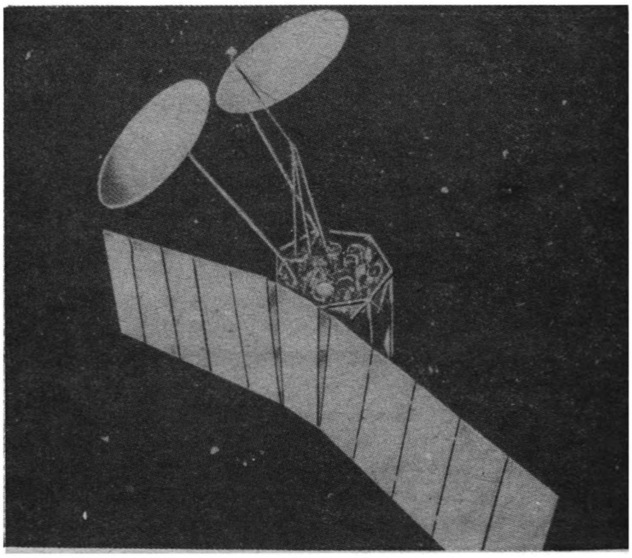




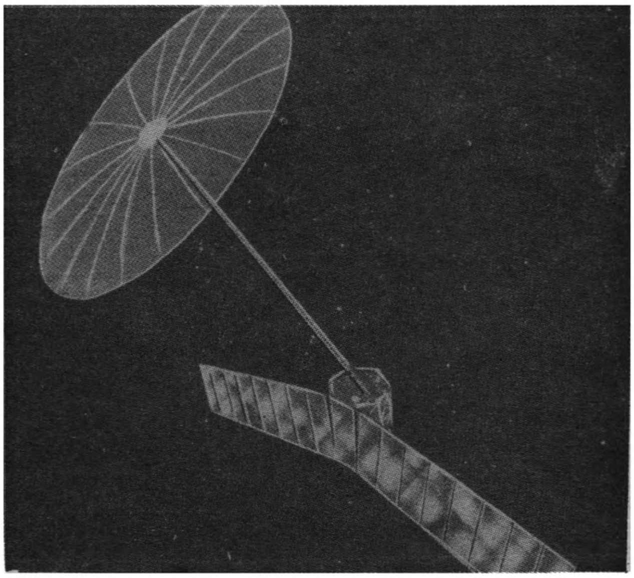
Wrapping geometry of solar panels on Duoloc. Maximum case of 22 panels (15 kW) is shown here. When wrapped, three panels remain explosed for transfer orbit power.



Big Communicator for TV broadcast. The array span exceeds 50 m, developing 15 kW to provide over 20 high power direct TV broadcast services for operation into home antennae less than 1 m in diameter.



Big Communicator for fixed services. A fixed service satellite that acts as a gateway within each cluster and to and from clusters. It carries additional inter-satellite laser link antennae for inter-cluster communications.



Big Communicator for mobile communications. This example for mobiles carries an 18 m mesh antenna operating at L-band for communications to land mobile vehicles; solar arrays generate 11 kW.

control equipment, which amounts to some two-thirds of the total input power, cannot be radiated through the solar cells that cover most of the body but has to be dissipated through a mirrored ring, and that is necessarily limited in diameter and axial length. In contrast, the 3-axis stabilised spacecraft, which is usually box-shaped, has two complete faces on that box which are not heated by the Sun, that is the North and South faces. (These faces do receive some heating at summer and winter solstices, but at a low angle of 23°). As a result, a 3-axis body of the same stowage dimensions as a classic spinner can dissipate more waste heat to the extent that the input power to the spacecraft can reach about 10 kW.

It became clear in our examination of the Big Communicators that we could not accept a continuation of this limit, even taking into account improvements in the efficiencies of payload and control electronic equipment. We therefore adopted a new configuration in which the whole body would be put into permanent shade behind a solar array that would lock permanently on to the Sun. For identification purposes we named these 'Duoloc' and 'Sunloc,' and we have conducted most of our design work on Duoloc.

Duoloc

The Duoloc body is an open framework, which is locked permanently on to the Sun, together with the solar array. Thus, while Duoloc is a 3-axis spacecraft, common to all British Aerospace classes, there are no rotating bearings and power transfer devices between the body and the solar arrays.

The body itself consists of an open framework into which is inserted a mirrored drum that rotates once per day. This drum, which is mounted on an internal bearing carried in the body, carries all the antennae and communications equipment required for the mission, and is locked on to the Earth. The drum is now effectively in permanent shade from the Sun, which means that its entire surface (except that facing the back of the array as the drum rotates) is available for dissipation of waste heat. As a result, the payload/mass ratio of Duoloc shows an advantage of two to one over today's 3-axis spacecraft.

A secondary advantage arises from a reduction in the number of bearing and power transfer assemblies from two to one; the one that is employed inside the body has to carry only the power associated with the payload and

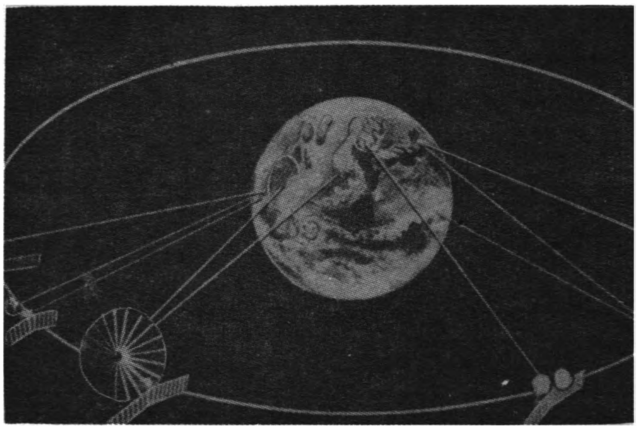


Diagram of Big Communicators in orbit showing inter-satellite links within clusters and between clusters. Note that, in contrast to today's inter-continental links that are provided by spacecraft over oceans, the Big Communicators are clustered over land masses to provide full coverage of those areas and link continents by laser.

not the additional power required by the spacecraft itself.

The solar arrays are given 'anhedral' for two purposes. Firstly, to give a clear line-of-sight for the antennae when they are at right-angles to the array and, secondly, to provide balancing against solar pressure.

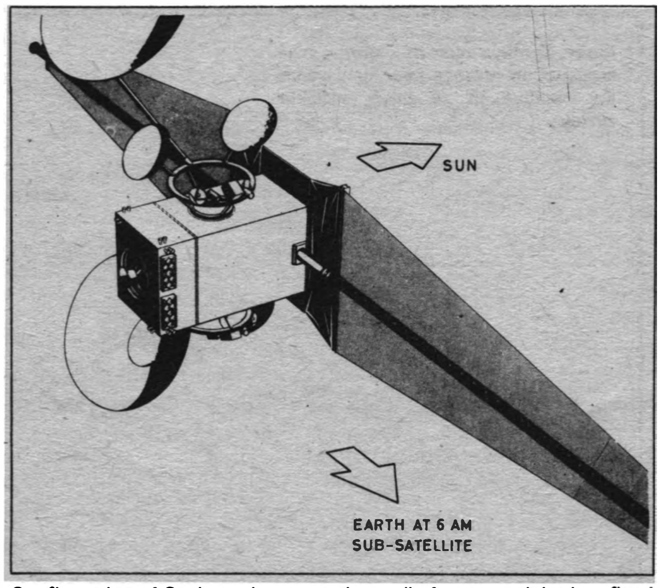
The open-framed body is seven sided. One face acts as a mounting face for the fixed central array panel, while the remaining six provide a symmetrical mounting for the wrap-round array panels. The number of wrapped panels can be varied from six (three on each side) to 22 (11 on each side) to provide a DC power range from 4 to 15 kW. In each case, power in transfer orbit, when the satellite is still in its stowed configuration, is provided by the central fixed array and by those wrap-round panels that expose cells when wrapped. In cases where multi-wrapping is used (more than three panels per side), the total number of panels is chosen to ensure that not less than two panels expose cells when wrapped. Thus, in the maximum case of 22 panels, wrapping occurs four times, but the last wrap contains only two panels, leaving two of the previous wrap exposed.

Stabilisation of the body is achieved by twin momentum wheels on a common axis, with additional wheel speed inputs driven from Sun sensors to compensate for Sun angle variations between equinoxes. The payload drum is driven off its central bearing, which is controlled by Earth sensors on the drum that also provide inputs to reaction wheels controlling the third body axis.

The body carries all spacecraft service equipment at its end opposite the antenna face, including attitude and orbit control thrusters, fuel supplies, batteries and telemetry, and is designed to mount directly on to Ariane 4 or into a liquid-fuelled perigee stage for Shuttle.

The design needs to be flexible to accommodate the various services that the Big Communicators will provide, namely fixed, mobile and broadcast services. Differences between these spacecraft are seen only in the array lengths and antenna configurations, the body remaining unchanged.

The principal difference in the operations of these satellites, in comparison with today's spacecraft, will be the use of inter-satellite links in clusters of Big Communicators and between clusters. The small antennae for these links can be seen in the drawings. This will permit clusters to be accommodated above land masses, providing total coverage for these areas with communications within and between clusters by carbon dioxide laser links. Thus, the traditional configuration of satellites over oceans to interconnect continents, with the inevitable limitation of land coverage that occurs in this configuration, will be replaced by laser-linked clusters of Big Communicators over each continent.



Configuration of Sunloc using a rotating radio frequency joint in a fixed spacecraft body instead of a rotating body.

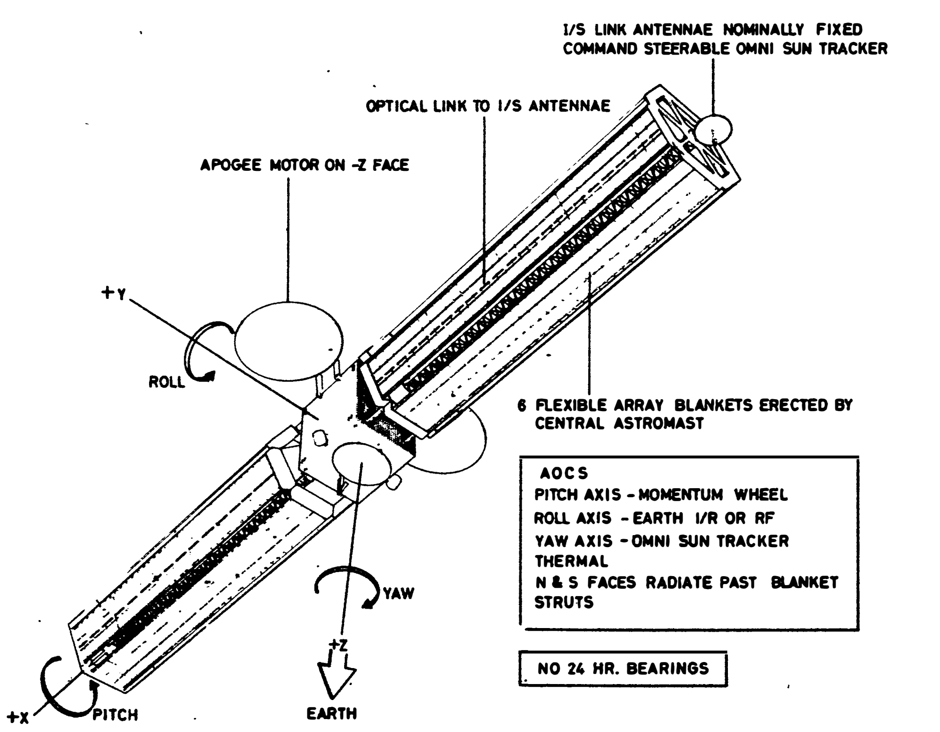
In common with developments proceeding throughout the communications world, Duoloc and its related Big Communicators will further enhance the traffic capacity of each orbital slot by employing continuously-evolving communications technologies, including scanning spot beams, on-board processing, variable power level amplifiers and variable dwell coverage. Typically, with its improved mass-carrying capacity and with new communications technologies applied, Duoloc will be able to handle ten times the capacity of an Intelsat 6 in a spacecraft that will still be lifted into orbit as a single payload on Ariane, or Shuttle, or by new launchers such as the British Aerospace Hotol.

Sunloc

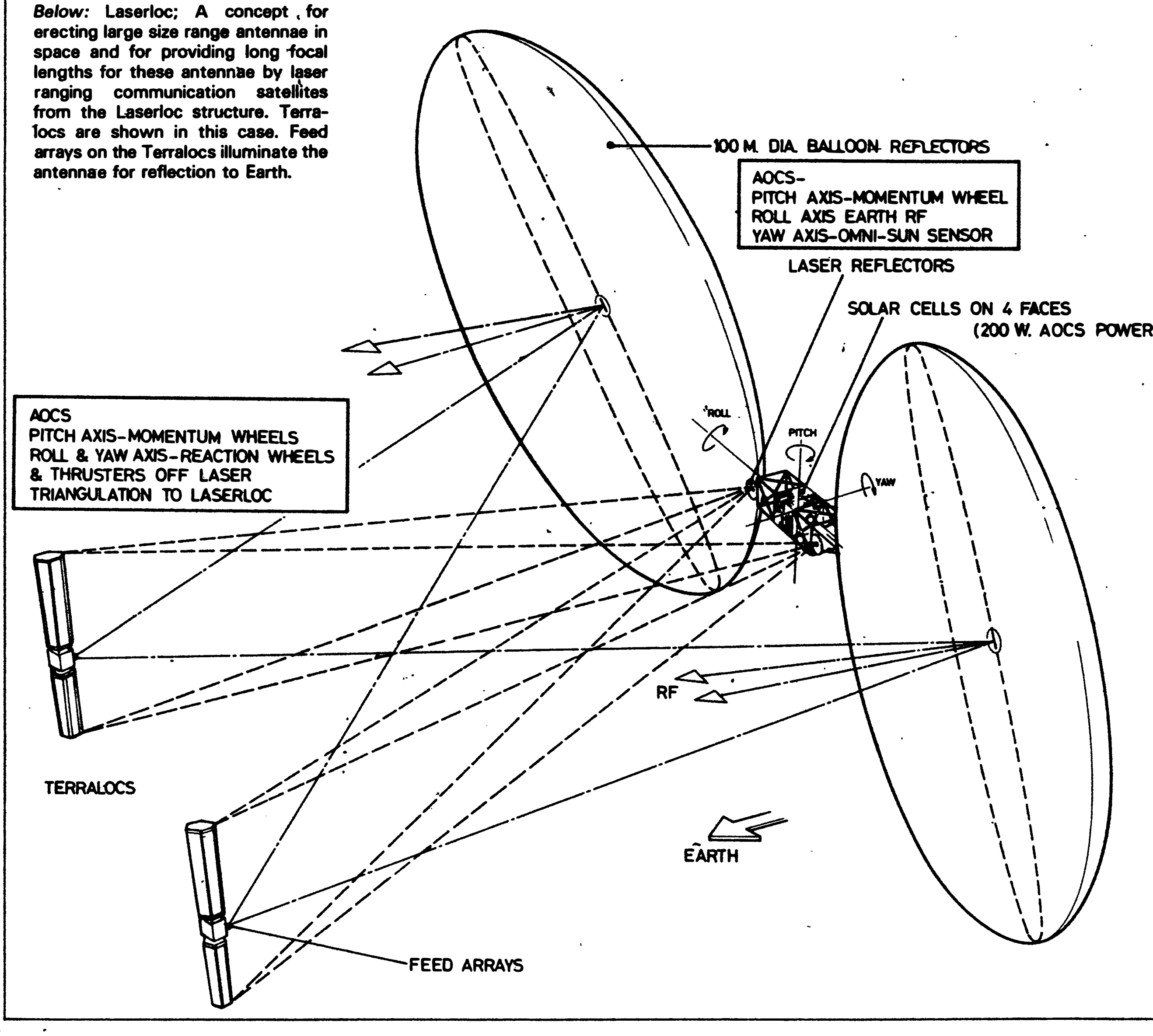
A variation on Duoloc is seen in another form of Sun-locked design in which the body reverts to the familiar box-shape of a 3-axis satellite. In this case, no bearing and power transfer assemblies are needed because the payload and all spacecraft control equipment are mounted within the body, which is fixed rigidly to the centre section of the array. In relation to the body, the antennae must rotate once per day, accomplished by mounting them and their feeds on open ring structures which are driven off rotating multi-band radio frequency joints mounted in the body. The central fixed array extends beyond the North and South faces of the body to the levels of the antenna rings. This provides two Sun shields to protect those faces from solar heating at 23° inclination during solstices. Thus, five faces of the box structure are permanently in shade and provide a very large mounting and heat-dissipation area in comparison with Duoloc and that available on a 3-axis body of similar size. Attitude and orbit control, using a combination of momentum wheels and reaction wheels, is similar to that on Duoloc.

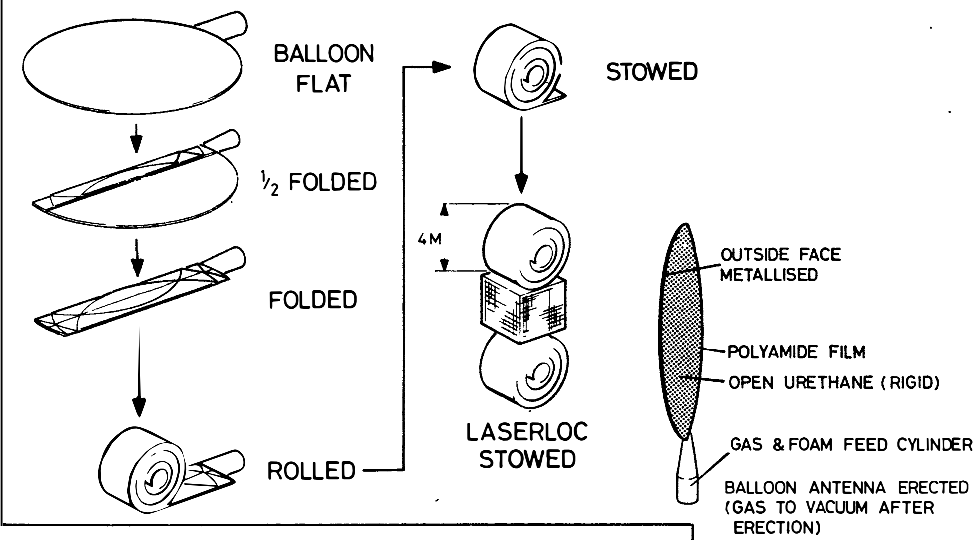
Because of the symmetry of design in Sunlock, no drooping of the array is required to balance solar torques, but tapering of the array is required to maintain a clear line-of-sight for the antennae at 6 a.m. and 6 p.m. at sub-satellite point, unless the antennae are mounted well clear of the body. In the example shown, the tapered array is flexible, erected by an astromast of the type used on Olympus.

Right: Configuration of Terraloc that contains no rotating bearings, which are needed on all other satellite classes.



Below: Laserloc; A concept for erecting large size range antennae in space and for providing long focal lengths for these antennae by laser ranging communication satellites from the Laserloc structure. Terralocs are shown in this case. Feed arrays on the Terralocs illuminate the antennae for reflection to Earth.





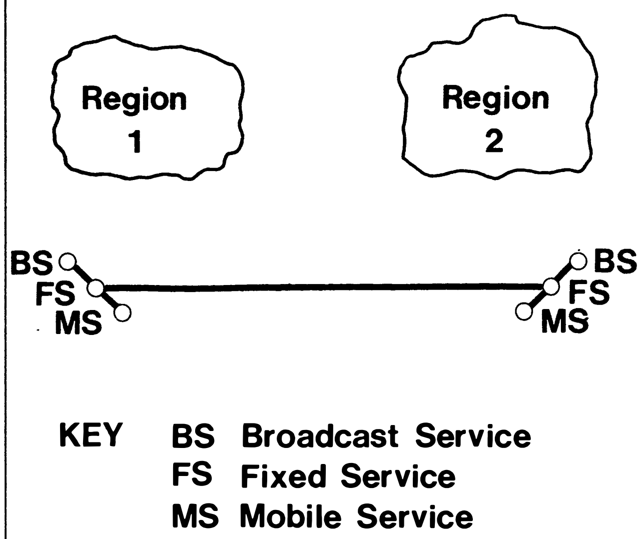
Left: Concept for the construction of large antennae in space with diameters up to 100 m, using gas-filled balloons with rigid foam and metallised on one outer face by vacuum deposition of metal, after erection.

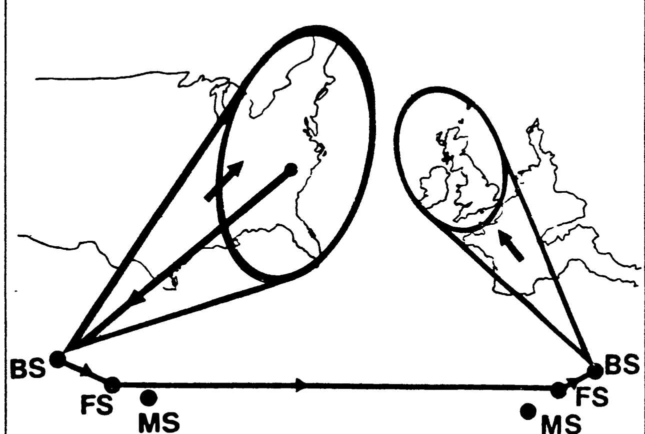
Below: Transoceanic intersatellite link between clusters. *Bottom:* Transmission of a US broadcast for UK Direct Broadcast Satellite *via* intersatellite links.

Terraloc

Mechanisms are an anathema to the satellite designer, who would prefer no moving parts at all. Another concept that approaches this target is Terraloc. This follows the classic 3-axis configuration, with the solar arrays aligned North and South, but the arrays themselves are formed as multi-faced polygons (six faces in this example) which are fixed to the body. As the spacecraft orbits the Earth, the body and the arrays rotate together once per day, with continuous illumination from the Sun on one side of the polygons. The number of solar cells is increased by a factor of Pi on the equivalent Sun-pointing array (as in a classic spinner) but no bearing and power transfer assemblies are required.

In the example here, the arrays are flexible, erected by a central astromast, but the concept can accommodate folding panel arrays and gas erected flexible arrays. The avoidance of moving parts after deployment is paid for by the limitation of heat dissipation area, which reverts to that equivalent to a 3-axis spacecraft of the same size.





Laserloc

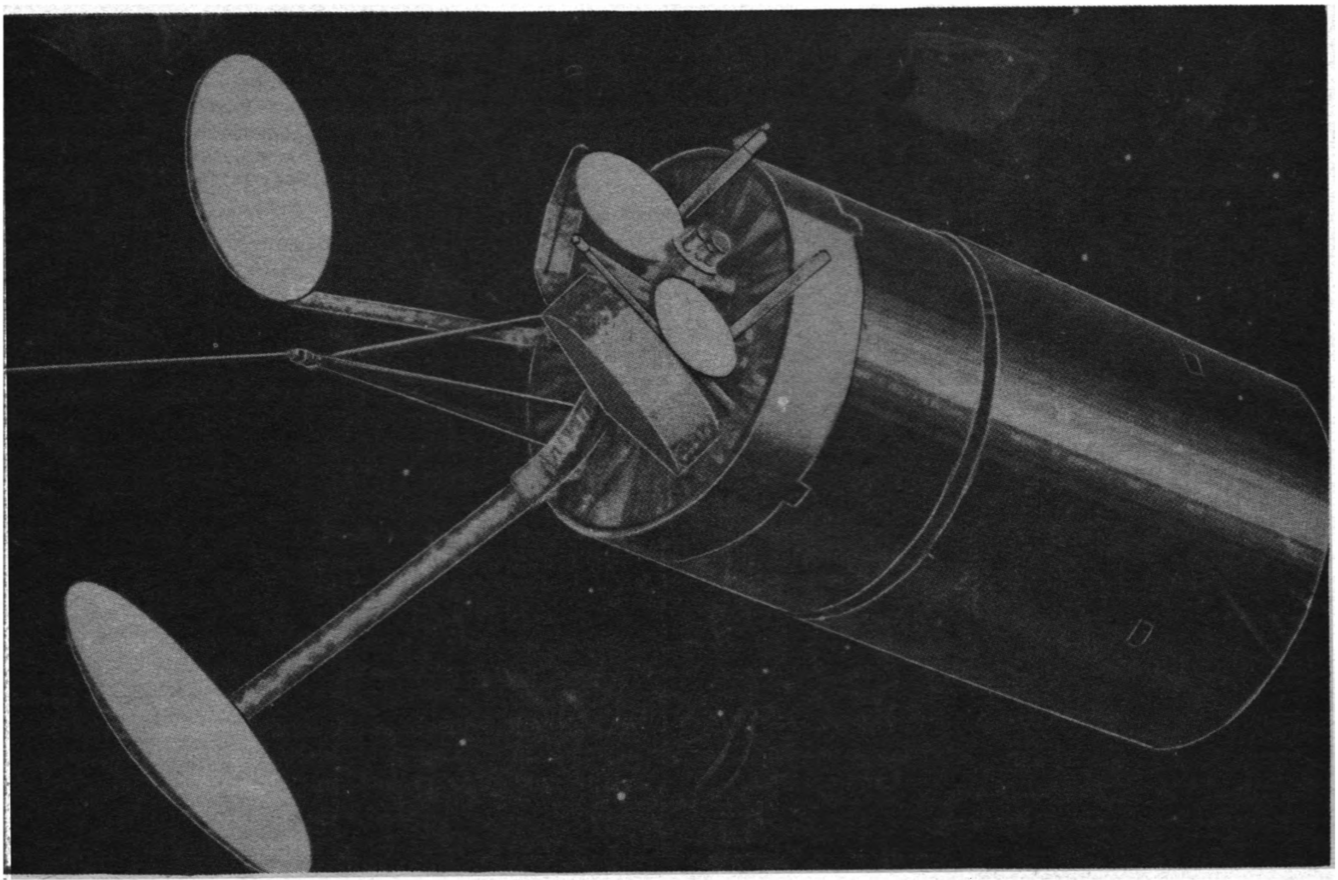
One of the trends that is becoming clearer in space communications is the drive towards larger and larger antennae, with diameters in the range of 50 m now in development. Antennae of this size are required to provide spot beams at the lower frequencies such as L-band and UHF for mobile users.

All the designs of large antennae so far have adopted complex erection mechanisms with hundreds or even thousands of parts to provide support for reflective meshes. Laserloc employs a different process for the construction of very large antennae and, in addition, uses an optical system for the establishment of co-located spacecraft and antennas in orbit.

Two very large antennae are mounted off a simple truss structure which carries sufficient solar power (around 200 watts) to maintain attitude, a small liquid perigee engine and added fuel to maintain station. To achieve reasonable beam shaping, a F/D ratio of at least one is aimed at in all spacecraft feed and antenna geometries. With a diameter of 100 m a focal length of at least 100 m is required, and the father away the feed is the better. Laserloc employes a laser ranging system in which one, two or more spacecraft are aligned to Laserloc using laser sources on the North and South extremities of the spacecraft pointing at reflectors on the central truss structure between the antennae. The spacecraft can be of any type, including Duoloc, Sunloc or Terraloc or any other three-axis or spinning spacecraft. The only difference on the spacecraft is that, instead of carrying Earth-facing antennae, they carry feed arrays on the opposite face, pointing away from the Earth.

In the example shown, the spacecraft are maintained in attitude and on-station by range and positional information fed from Laserloc, but the situation can be reversed, in which case Laserloc is maintained by ranging off the spacecraft, which carry their normal attitude control and station-keeping equipment.

As mentioned above, Laserloc uses a different form of



The Intelsat 6 series, spinning satellites with a DC power of 2.2 kW, will begin operations in 1986 following launch from the Shuttle. Ariane will also be used as a launcher, beginning in late 1987.

construction in which a 100 m antenna can be constructed from a two near-flat sheets of polyamide film, which are folded and rolled for stowage before deployment in space. Laserloc is taken into low-Earth orbit as a single payload in its stowed form. Once on station, the central truss section is extended and a supply of gas is released into the rolled-up film to form a balloon of lenticular cross section. The gas is followed by an injection of open urethane foam which sets rigidly, with the gas allowed to escape to vacuum through the foam *via* relief holes on the periphery of the balloon. The 'rear' face of the balloon (non-Earth facing) is then metallised externally by vacuum deposition of aluminium or a similar metal, using an astronaut to apply the metal, giving a parabolic reflector with a surface accuracy equal to that of the stretched balloon film. The entire assembly is then lifted to geostationary orbit by its low-thrust liquid engine.

Using the Big Communicators

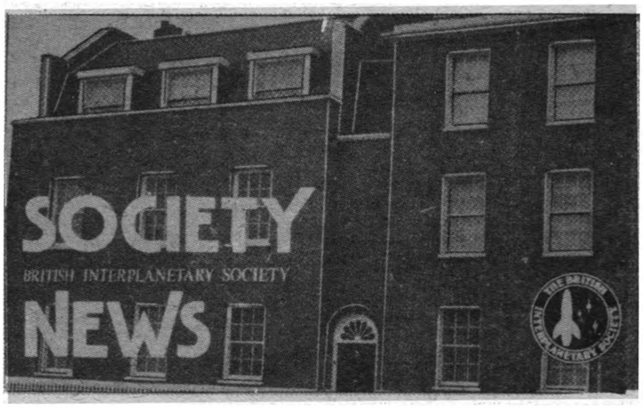
Whatever form the Big Communicators take, be they Duolocs, Sunlocs, Terralocs or Laserlocs, their presence in orbit will be felt by an ever-expanding population of telecommunications and TV carriers and users.

The users will see smaller and smaller Earth stations carrying increasing quantities of traffic. With direct broadcast TV, for example, indoor home antennae about 30 cm diameter will be familiar and it is unlikely that dishes larger than 60 cm will ever be used. For the commercial user, 1 m antennae operating in Ka-band will be handling 100 Mbits/sec of mixed voice, data and video between corporate sites separated by thousands, or hundreds or tens of kilometres.

It is the carriers who will experience the biggest changes. As mentioned earlier, the Big Communicators will carry laser intersatellite links for communications within clusters of Big Communicators and between clusters. Clusters, containing broadcast, mobile and fixed service versions of the Big Communicators, will be stationed over land masses to provide total wideband coverage of complete nations, regions and continents, and will accommodate the massive expansions in traffic that are to be expected across these land masses. Then, instead of coupling continents by placing satellites over the intervening oceans, using gateway terminals near the shores, which is the conventional practice today, the Big Communicators whill achieve that coupling *via* transoceanic laser links, with further links inside the clusters to couple the various versions of the satellites.

Thus, a TV broadcast emanating from a USA source could be linked from the local broadcast satellite to the nearby fixed service satellite, which will transfer the signal across the Atlantic to the European fixed service spacecraft, and thence to the European direct broadcast satellite. Equally, a call from an office in Europe can be patched through the cluster to the local mobile satellite, which will radiate the signal to an addressed truck somewhere else in Europe, or indeed, somewhere in the USA, again *via* the fixed service gateway satellites. All forms of national, regional, continental and inter-continental traffic will be handled in this way, with tomorrow's PTTs aiming to retain control of the fixed service gateway satellites. This they might well do, but one can foresee the world's broadcasters questioning the need to link through the gateways. Their spacecraft will also carry laser link antennae and they will see the advantages of direct links between broadcast satellites; so will the mobile operators.

Certainly, the Big Communicators of tomorrow will lead to fundamental changes in the way we accept that traffic is carried today.



A Flying Visit

The Society was very pleased to welcome as its Guest one of its most distinguished Fellows, Claude Nicollier (the Mission Specialist astronaut scheduled to participate in a Shuttle flight this year) accompanied by Dr. Dai Shapland from ESA headquarters. Both guests were welcomed by the Society's President, Mr. Anthony Lawton, together with representatives of its various committees and administrative staff.

Claude took the opportunity to recount some of his experiences as one of the three ESA Spacelab specialists, one of his colleagues, Wubbo Ockles, having already addressed the Society on this topic during Space '84 in Brighton last November.

Claude, who is currently training at the Johnson Space Center in Houston, began by describing a Shuttle flight. He explained that, with 15 sunrises and sunsets in a single day, space is certainly the place to go if one likes that sort of thing. Re-entry was a most spectacular event, particularly at night, with the high-temperature pink glow surrounding the orbiter very conspicuous.

Claude's main topic was that of selection and training. Both Shuttle commander and Pilot have, basically, the same training, concerned mainly in dealing with problems of ascent, landing and orbital manoeuvres. Much of their time is spent training for emergency procedures of all types. Mission specialists receive a wide general training and are responsible for the remote manipulator arm; two of them are always ready to go out on EVA if necessary. Payload specialists, on the other hand, receive relatively short training and, as a consequence, this grade covers a wide spectrum of candidate.

Claude Nicollier (centre) with Tony Lawton (left) and Dr. Dai Shapland in the Society's Reception Room. *H. J. P. Arnold*

The first ESA specialists were recruited in late 1977 and began by submitting to extensive medical examinations. These included tests on motion sickness, with a deliberate attempt to create conflicts between the brain and eyes.

Particularly interesting was his account of training in an aircraft specially adapted with Shuttle controls, using a fly-by wire system where one really could learn how to land, in a manner not possible in a training simulator. Much additional training took place at Johnson in a water immersion tank, principally to acquire experience in the use of hand tools during EVA.

Further training took place in an aircraft that provided periods of 30-second weightlessness by moving in parabolic paths in quick succession, often 30 to 60 one after the other.

Like other Mission Specialists, he was also given a particular job to do - in his case it was to learn about software. This took nearly eight hours a day, the other training occupying only about 10% of his time. As he dryly remarked, 'There is no higher authority than the computer.'

At the end of the meeting Claude presented the Society with a picture of the Shuttle taken from the German SPAS platform, suitably inscribed, mentioning that he had chosen it because it was a significant and beautiful picture.

Meeting the Shuttle 51A Astronauts

The Society's President, Anthony Lawton and Executive Secretary, Len Carter, represented the Society at a gathering of distinguished guests to greet the arrival of Fred Hauck, Dale Gardner, Joe Allen, David Walker and Anna Fisher, the crew of *Discovery* following their highly successful Shuttle 51A flight last November.

This took place at the home of the American Ambassador in Regent's Park on Monday 11 February. Also among the gathering were two former members of the Council, Peter Conchie and John Becklake, and two evergreens of the media, Reg Turnill (BBC) and Frank Miles (ITN), both BIS Fellows. Representing the Department of Trade and Industry were Jack Leeming and Cliff Nicholas.

After the opening welcome, the crew gave a joint presentation, accompanied by a film, of their epic flight, laced with plenty of humour and put over in a warm and friendly fashion. There was no doubt that the audience was thrilled at the opportunity to meet the crew and to hear, at first hand, the tale of some of their exploits. First hand information always provides unusual aspects. For example, Fred and Dale told us that during re-entry the predominent plasma colour seen by the human eye is *green*. Most film shows the dominant colour as *red*. They explained this by saying that both colours are present but the eye, being more sensitive to green, sees that colour, whereas a colour film is more sensitive to deep red.

The Shuttle comes in over the threshold and touches down at about 195 knots. The stalling speed is typically 150 knots (depending on overall weight) but a liberal margin of 40-45 knots is used to ensure adequate control at a safe landing speed.

The nose seems to smack down sharply as the speed drops but this is largely an illusion. The typical landings are less bumpy than that of a Boeing 747 Jumbo Jet.

We are both greatly indebted to our hosts, the Ambassador and his wife for their kindness and hospitality in arranging such a stimulating evening.

SATELLITE DIGEST -183

Robert D. Christy

Continued from the April issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

VEGA 2 1984-128A, 15449

Launched: 0914, 21 Dec 1984 from Tyuratam by D-1-E.
Spacecraft data: Similar to Vega 1.
Mission: As Vega 1.
Orbit: Heliocentric.

1984-129A 15453

Launched: (0000?), 22 Dec 1984 from Cape Canaveral AFB by Titan 34D.
Spacecraft data: Not available.
Mission: Military, possibly communications.
Orbit: Geosynchronous.

SAKIGAKE (MS-T5) 1985-1A, 15464

Launched: 1915, 7 Jan 1985 from Kagoshima by Mu-3S.
Spacecraft data: Cylindrical in shape, with the curved surface covered in solar cells. The length is 0.7 m, and the diameter 1.4 m, the mass is 141 kg. It employs spin stabilisation at 5 rpm, and carries low thrust gas jets for minor course corrections.
Mission: Third launch of a spacecraft under the International Halley Watch (see also Vega 1, Vega 2). It was originally intended as an engineering test prior to the Planet-A launch later in 1985, but will now pass 1,000,000 km ahead of Halley's comet through the expected magnetospheric bow shock.
Orbit: Heliocentric.

COSMOS 1616 1985-2A, 15467

Launched: 1045, 9 Jan 1985 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and cylindrical, supplementary payload at the forward end. Length about 6 m, diameter (max) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaissance.
Orbit: 173 x 358 km, 89.83 min, 64.93° manoeuvrable.

COSMOS 1617-1622 1985-3A-F 15469-15474

Launched: 1519, 15 Jan 1985 from Plesetsk by F Vehicle.
Spacecraft data: Possibly similar to the small satellites normally launched in groups of eight by C-1, i.e. spheroid in shape, 1 m long, 0.8 m diameter and mass around 40 kg.
Mission: Military communications.
Orbit: 1384 x 1414 km, 113.82 min, 82.61° (lowest), 1413 x 1415 km, 114.15 min, 82.62° (highest).

MOLNIYA-3(23) 1985-4A, 15476

Launched: 0622, 16 Jan 1985 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with conical motor section at one end, deriving power from a 'windmill' of six sola panels. Length 4 m, diameter 1.6 m and mass around 2000 kg.
Mission: Communications satellite providing telephone, telegraph and TV links through the 'Orbita' system, both within the USSR and abroad.
Orbit: Initially 625 x 40646 km, 736.42 min, 62.88° and later lowered to 618 x 39751 km, 718.06 min to ensure daily ground track repeats.

COSMOS 1623 1985-5A, 15479

Launched: 0820, 16 Jan 1985 from Tyuratam by A-2.
Spacecraft data: As Cosmos 1616.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 349 x 415 km, 92.22 mins, 69.99°.

COSMOS 1624 1985-6A, 15482

Launched: 1749, 17 Jan 1985 from Plesetsk by C-1.
Spacecraft data: Possibly a cylindrical body with domed ends enclosed in a drum-shaped solar array. Length and diameter both about 2 m and mass around 700 kg.
Mission: Military communications, using a store/dump technique.
Orbit: 785 x 807 km, 100.84 min, 74.04°

GORIZONT 11 1985-7A, 15484

Launched: 1026, 18 Jan 1985 from Tyuratam by D-1-E.
Spacecraft data: Cylinder with a pair of solar panels, at one end is a dish aerial array. Length 5 m and diameter 2 m, with mass around 2000 kg.
Mission: Communications satellite providing round the clock telephone, telegraph and TV links through the 'Orbita' system both within the USSR and abroad.
Orbit: Geosynchronous above 145°E longitude (near Statsionar 7).

COSMOS 1625 1985-8A, 15492

Launched: 1956, 23 Jan 1985 from Tyuratam by F-1.
Spacecraft data: Not available.
Mission: Probably intended as an electronic reconnaissance satellite covering ocean areas. The mission failed owing to a re-start failure of the upper rocket stage, it decayed within hours.
Orbit: 116 x 370 km, 89.36 min, 65.01°.

COSMOS 1626 1985-9A, 15494

Launched: 1646, 24 Jan 1985 from Plesetsk by F-vehicle.
Spacecraft data: Probably a cylinder with two Sun-seeking solar panels. Length about 5 m, diameter 1.5 m and mass around 2200 kg.
Mission: Electronic reconnaissance.
Orbit: 630 x 664 km, 97.73 min, 82.52°.

STS-51C 1985-10A, 15496

Launched: 1950*, 24 Jan 1985 from Kennedy Space Center.
Spacecraft data: Delta-winged vehicle, 37 m long and 24 m across with mass around 70 tonnes (excluding payload).
Mission: Carried crew of Thomas Mattingly, Loren Shriver, Ellison Onizuka, James Buchli and Gary Payton (all military), to launch a classified, military payload. (Landed Kennedy Space Center at 2123, 27 Jan 1985).
Orbit: Approx 300 km, circular, 90 mins, 28.5°.

USAF Payload (1985-10B?), (uncatalogued?)

Launched: Approx 1200, 25 Jan 1985 from the payload bay of *Discovery* by Inertial Upper Stage.
Mission: Military, possibly combining electronic reconnaissance with military early warning.
Orbit: Geosynchronous.

COSMOS 1627 1985-11A, 15505

Launched: 1936, 1 Feb 1985 from Plesetsk by C-1.
Spacecraft data: As Cosmos 1624.
Mission: Navigation satellite.
Orbit: 964 x 1027 km, 105.08 min, 82.92°.

COSMOS 1628 1985-12A, 15514

Launched: 1100, 6 Feb 1985 from Plesetsk by A-2.
Spacecraft data: As Cosmos 1616.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 355 x 415 km, 92.30 min, 72.85°.

METEOR 2(12) 1985-13A, 15516

Launched: 2146, 6 Feb 1985, probably by F-vehicle.
Spacecraft data: As Cosmos 1626.
Mission: Meteorological satellite returning scanning radiometer and other remotely sensed data on the Earth's surface and cloud cover.
Orbit: 939 x 959km, 104.08 min, 82.54°.

FROM THE SECRETARY'S DESK

HQ History

We have culled a little more about our present premises from the centenary issue of *Dalton's Weekly* which appeared in 1970. It appears that the printers of the magazine, E. & S. Hebert, first produced it in 1870 as a 4-page broadsheet from No. 21 South Lambeth Road, then expanding their base to incorporate No. 23 as well.

In March 1932 the business became a private company (E. & S. Hebert Ltd), at which point the company expanded further to build new offices on the sites of 25 and 27. After the war, c1969, numbers 21, 23 and 25 were all demolished to make way for a road widening scheme, thus leaving only No. 27, a somewhat garish yellow and green building in art-deco style. By this time the company had changed its name to Dalton's Weekly Limited and moved to new premises in south-west London, leaving No. 27 empty and derelict.

The whole area, including No. 29, also empty and derelict but which had not been part of the Dalton's premises, was then bought by a property speculator with a view to redevelopment. Things did not go according to plan, helped least of all by a decision of the local Council to declare No. 29 a Grade 2 listed building. Soon afterwards the developer went into liquidation, thus freeing the two remaining buildings for other use.

At that point the Society stepped in to acquire No's 27-29 and has since regretted that it did not take the plunge and acquire the vacant properties to the rear at the same time.

The whole area will soon be made into a Preservation Area, so that no changes or future development can take place without permission.

Outward Bound

I have the lesser-known task of looking after our building. It doesn't sound much, but there's more to it than meets the eye. During the recent cold spell, for example, some cement rendering under the roof of No. 29 (the listed building forming part of our premises) fell to Earth. It didn't appear serious but the builders would have none of it. They detected cracks in the brickwork, a bulging of the brickwork at the front and suspected subsidence of the foundations extending to the pavement nearby.

The local Historic Building Department quickly arrived on the scene, stern of face and serious in intent. There was a need for vibration tests, strain gauges and a Structural Engineer to undertake further tests. Greater London Council Representatives arrived soon afterwards with black boxes for prolonged noise and vibration tests.

It was a bad day.

Bayer's *Uranometria*

Members will have seen from the March issue that the Society is about to launch a limited facsimile edition of Bayer's *Uranometria,* an oustanding compilation of star maps that appeared in 1603 and, in the case of this particular copy, containing extensive additional observation made about 1747-9, possibly observations by James Bradley, the fourth Astronomer Royal, whose data was extensively used by many later astronomical luminaries. For example, the star positions determined by Bradley were essential to F.W. Bessel in calculating the positions given for one century in his "Tabulae Regionmontanae" for measurements of the position of the Sun, planets and stars.

The story of Bradley's sojourn as Astronomer Royal and especially the goings-on between his family and the authorities at Greenwich Observatory after his death, culminating in a raid on the Observatory by members of his family to cart away his belongings hook, line and sinker, is probably best told elsewhere. For now, it is interesting to reflect upon how the Society came by its own notable volume.
which appeared in 1603 and, in the case of this particular copy, containing extensive observations believed to have been made by James Bradley, the fourth Astronomer Royal, and used extensively as basic data by Flamsteed, who succeeded him, and many later astronomical luminaries. For example, the star positions determined by Bradley were essentail to F.W. Bessel in calculating the positions given for one century in his "Tabulae Regionmontanae" (1830), thus providing the first modern reference system for measurements of the positions of the Sun, planets and stars.

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Bradley lived in Gloucestershire and, true to form, the Bayer Atlas reached the Society from that part of the world. It was sent wrapped in newspaper, in a badly chewed-up condition and indistinguishable (apart from accumulated dirt) from any bundle of scrap paper found anywhere. It reached my desk in the form of one oustretched hand holding the string which kept the contents together, and the other carefully pinching the nose. It was touch and go whether the contents went on to the desk or straight in the wastepaper basket.

Many of the pages had been stuck together (with plum jam apparently) in the distant past, many were badly faded or were torn, so the general appearance was very dismal.

However, careful perusal of those pages still discernible gave cause for rising excitement. The first stage was to have the book repaired and with all the pages made intact. Pages stuck together had to be dis-glued and everything photographed before any further damage could ensue. As it turned out, excitement was not confined to us. The craftsman undertaking the repair was equally enthralled at the volume and lavished care and attention on it.

Not only did he shut himself away for weeks on end, carefully and tenderly repairing each page but, by all accounts, it gave him a great boost in life. Even the subsequent re-binding was turned into a work of art. *Any* piece of calf wouldn't do. It had to be a complete skin, in pristine condition and, apparently, a skin among skins.

In the interim, the book was returned as a number of loose pages *en route* to the photographer, whereupon the photographer, too, went into paroxysms of delight, executing the same mental symptoms as the page repairer had done beforehand. He told us that the pages arrived

in the first place with the happy remark "Here's a load of old junk for you." The messenger was lucky to escape with only a flea in his ear and not a well-aimed boot in his rear. Once again, a dedicated labour of love was expended on the book to produce the best possible photographic reproductions of every detail.

In due course, everything was brought together; the book duly arrived back at Society HQ properly re-bound, now in beautiful condition and with every chance of being saved for posterity.

Meanwhile, efforts were being made to identify the author of the mass of later observations made and inserted into the book and which, quite obviously, amounted virtually to a re-check of all the positions first determined by Bayer and must have represented the labour of several years. There is no signature and attempts are still being made to identify the 18th century writing.

All in all, it seems that a chunk of history came unerringly to the Society, after hundreds of years, thus giving us the opportunity of sharing the discovery with all members who would like to possess a copy of a limited edition of an exact replica of our possesion.

This is a unique work on so many counts. Our Society has been very fortunate.

Come, Join Us

I wish I could persuade many more members with UK bank accounts to adopt the Direct Debit method of settlement of their annual dues. It is so simple and cuts out so much work, both to the members and to ourselves.

When we adopted the scheme we had in mind the idea of persuading a minimum of 1,000 members to join. To date, we have about 700 so we are anxious to fill the balance.

Joining the Direct Debit scheme requires the completion of a very simple form which has then to be sent direct to the member's bank. Thereafter, the whole procedure is automatic. The subsequent saving in time is enormous, even contemplating only the time otherwise spent in opening hundreds of envelopes, checking their contents, entering up remittances, adding and then paying them to the bank. All can be cut out in one blow.

Direct Debits can be cancelled at any time (but please tell us if you do so!) and there are in-built safeguards against mistakes.

I cannot urge too strongly to members to give it a try, even if for a year or two. Forms, effective now from 1st January 1986, can be had for the asking.

Scoops

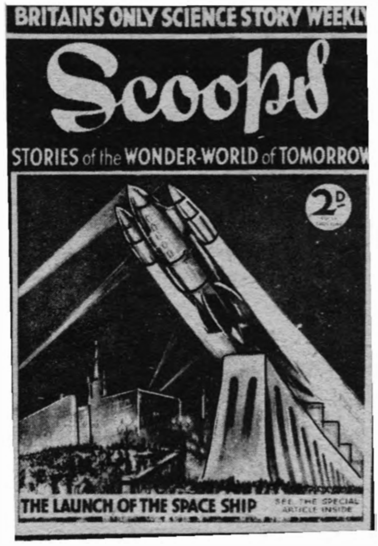
I was fascinated to see copies of *Scoops* the other day. This was a boy's magazine issued in 1934 which I read avidly, not least because it contained a column contributed by our founder, Phil Cleator. About this time Phil was pestering magazine editors throughout the country in his quest to assail their unsuspecting readers with the glad tidings that the conquest of space was impending and that the BIS had recently been founded to hasten the process.

If I remember right, Phil's entrée to the magazine stemmed from his rejoinder to Sir James Jeans, then at the height of his fame and not particularly keen on space travel. It warmed the cockles of my heart.

Sadly, *Scoops* came to an early end so Phil only provided it with eight contributions altogether.

In retrospect, his column still makes absorbing reading. For example, one dated 16 June 1934 describes how, with Professor A.M. Low and several other members of the Society, he interviewed Gerhard Zucker 'who hopes

Britain's first science fiction magazine appeared in 1934 and regularly included BIS news.



to shoot his postal rocket here in England.' Not only that, Zucker's plan, should his first attempt be successful, was 'to construct much larger rockets with a view to establishing a regular postal service between England and the Continent. In the same issue Phil mentions his invitation to the late Willy Ley to come to England, having met him in Berlin earlier that year. Willy, he reports, spoke English, French and Russian fluently, besides his native German. (Willy Ley subsequently became a long-standing Fellow of the Society and the author of many books on space travel including *Rockets and Space Travel* which ran to numerous editions).

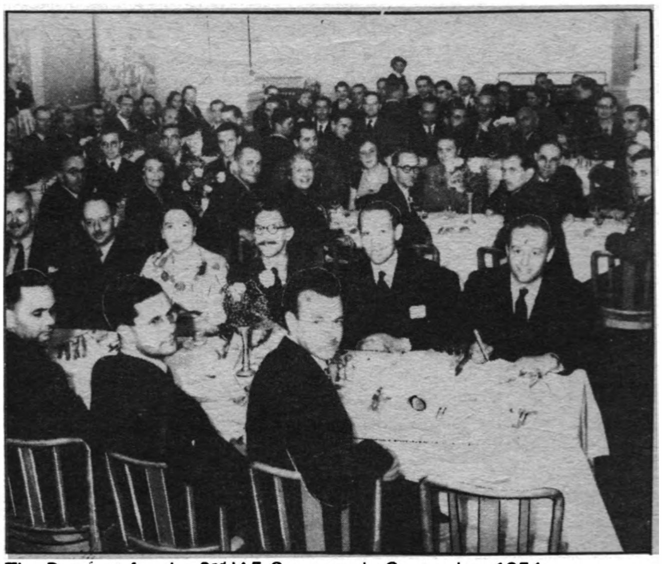
A Little Recitation

Preparing the writeup on each annual IAF Congress invariably brings back a host of memories, some pleasant, some involving trials and tribulations. The 1951 (London) Congress, for example, really fell on us out of the blue. There were no precedents, apart from extensive pre-correspondence concerned more with trying to agree a Constitution than anything else. We were left to our own devices to decide what form the Congress should take, leading to a plan for technical, business and social sessions still adopted today. We had a staff of one, so helpers were conjured out of thin air. All needed pre-training. Thought had to be given to the layout, order of events, programme, interpreters, badges, banquets, transport, hotel and a host of other things, all organised for the first time.

Substantial publicity from the picture of Arthur Clarke, Val Cleaver and myself staring at a miniscule model of a V-2 shows how little we really had to show for it at that time!

All technical and social meetings were held in Caxton Hall, the social occasions next door at St. Ermin's Hotel. Practically everything went off splendidly though the largely politically-motivated decision to site the IAF Secretariat in Switzerland subsequently become something of an albatros.

The second London Congress (1959) in Church House, was somewhat grander, this time being opened by a Minister of State and including an Official Reception at Lancaster House. It was at this point that the multi-session problem began to intrude, though actually it was the least of our troubles. The problems which bedevilled us stemmed from a National Printing Strike. We were hard-put to find anyone to print even the programme. Another problem was a large sign marked 'EXIT.' Actually it was no such thing; opening it invariably set all the alarm



The Banquet for the 2nd IAF Congress in September 1951.

bells ringing. A sad event was the death of Progessor Zarankiewicz, who was actually chairing a major session at the time. We had had the foresight to engage a doctor but he turned out to be somewhere else at the time. The subsequent bankruptcy of the official photographer ensured that we ended up with no pictures at all to show for our labours! We also had the problem of the two large chauffeur-driven limousines placed at our disposal for a whole week. It was impossible to find anything for them to do.

The Varna (1962) Congress also springs to mind. On that occasion I had a complete hotel all to myself. It was very eerie at night, with lots of echoing corridors. I became panic-stricken, towards the end, for fear of oversleeping and missing the only plane back.

Other early congresses might have worked out better if it hadn't been for 'trouble t'mill.' This was nothing to do with the office, which operated normally throughout, but arose because we tried to run other Society functions at the same time. The lack of synchronization produced a chain of accidents, upsets and general annoyances.

Nowadays, with a more disciplined approach, we tend to put our Ship of State into a sort of slow wallow during Congress week: it makes it easier to climb aboard on our return.

Making One's Mark

A film on early motor racing the other day featured Prince Bira of Siam. The Prince, a former Member of the Society, led me to recall others no longer with us but very distinguished in their day. Foremost in underwater exploration was Dr. William Beebe, of Bathysphere fame. Yvonne De Carlo still retains the aura of a famous film actress though George Bernard Shaw (who insisted on paying his subscription on 1 July instead of 1 January, until tricked into remitting in advance!) has passed away. I also remember Dr. Marie Stopes, a pre-war authority on birth control and well qualified in solving population problems of an interstellar ark.

Cut to the Quick

There is no sight more sorrowful than that of an author whose paper has been edited - not every author I hasten to add, for most realise that those who take the trouble to edit seek to improve, for no personal kudos and do it on a 100% hiding to nothing basis.

As an author so mutilated I know the pain, but there is also the ecstasy when the text appears in print, improvments by others then being conveniently ignored and full praise taken for the final version.

In a slightly different category are those whose material has been rejected. Some accept it cheerfully e.g. I once wrote an article on Mars. It was never published. I read the text again some years later and am not surprised.

Others, however, feel so cut to the quick that their response is quite unforgiving - if not vitriolic. Usually, one "hasn't read the paper." Sadly, "one has."

The truth can hurt.

New Society Logo

The Council is considering updating the Society's logo. They hope to improve it in several ways, by indicating the name of the Society more clearly and including the Moon (or a similar airless celestial world) to indicate our pathway to the stars. The aim is to achieve a much higher-quality result that members will be proud to adopt.

The new logo is not likely to be available until next year but it will appear on new-style badges and patches then, as well as in the Society's magazines. Announcements will appear in *Spaceflight* when all is ready.

Our new logo will still be clearly identifiable with the previous logo, which ran for nearly 25 years and which was chosen as the result of a competition. It subsequently found its way into a variety of forms, all of which will be continued but using the new version.

The new-style logo would be the third used by the Society

The logo to be superceded was not actually the first adopted by the Society. We had a pre-war logo, designed by Phil Cleator (our Founder), which was used on letter-paper at the time though never as a lapel badge. It also had the distinction of appearing in a film, to the astonishment of members attending a film show shortly after the end of the war to see a German film, produced during hostilities, entitled 'History of Rocket Development.'

Commercialization of Space

A Yorkshire firm of undertakers is offering the ultimate funeral service to its customers - a rocket-powered send-off. Interested customers could range from thoughts of a peaceful journey, an interest in space travel or simply the wish to get away from it all.

Services offered include a layout in deep space or a package tour, just outside the Earth's atmosphere.

Another twist to the story came from the report in the *Houston Chronicle* of 20 January that Space Services Inc. have "talked to about half a dozen other firms, all interested in sending cremated remains off the planet," but "there was no indication of the cost of space funerals to potential customers." Presumably, they would have little interest.

Wonderful Thought

Extract from a recent letter requesting a batch of magazines free of charge:

"Naturally, I will be willing to pay for postage if the BIS does not receive free mailing service from the British Government."

James E. Keeler: Pioneer American Astrophysicist
D.E.Osterbrock, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, 1984, 411pp, £35.

This book provides a biography of a distinguished pioneer of astrophysics who was concerned with the application of physical methods to understanding the nature of stars, nebulae, planets, comets and other objects in the Universe. Keeler, the first astronomer at the Lick Observatory, had a career closely linked with that of George Ellery Hale, founder of the Yerkes Observatory, so the book gives much detail of the early history of these two observatories. In two short years he photographed hundreds of spiral nebulae with the Lick Observatory reflecting telescope and recognised them as important constituents of the Universe, thus marking the beginning of the scientific study of the galaxies. He was a keen participant in the first international astronomical meetings held in the USA and was one of the founding editors of the *Astrophysical Journal*, the first professional journal in the new field he helped to create.

In his time he was considered to be the leading astronomical spectroscopist of his generation, he died in 1900 at the early age of 42 and then at the peak of his career. Today, he is little known and even though his discoveries are still referred to in astronomy courses everywhere they are no longer associated with his name.

Canon of Solar Eclipses 2003 BC to 2526 AD
H. Mucke and J. Meeus, Astronomishes Buro, Hasenwartgasse 32, A-1238 Wien, Austria, 908pp, 1983, 1,153 Austrian Shillings (Paperbound).

This substantial reference volume is a counterpart to an earlier volume *Canon of Lunar Eclipses* published in 1979.

It contains data for 10,774 solar eclipses based on the solar theory of Newcomb and the improved lunar theory of Brown. Of these 6,886 are central, leading to an average of 237.8 solar eclipses per century. The aim, in a book covering eclipses over no less than 45 centuries, was to obtain an accuracy of 0.1 minute of time. Besides data on each eclipse, diagrams are included showing the passage of each eclipse over the Earth's surface

After an introduction in English and German, the book really falls into two parts. Part 1, the catalogue papers, provides general data and Besselian elements for all the solar eclipses considered: Part 2 contains the corresponding maps for each eclipse, showing its region of visibility, both reproduced directly from the computer printout. Column one of the catalogue contains the number of the Saros cycle to which each eclipse belongs. (A Saros cycle is a period of 223 lunations or 18 years and 11 days appx.) The small picture of the Earth globe given for each eclipse provides an outline of the continents and principal islands, the orientation being such that the depicted hemisphere is the one directed towards the Sun at the time of maximum eclipse. These maps show the regions of partial eclipse as well as the central tracks.

Astrodynamics 1983 Vol. 54 Parts I and II, Advances in the Astronautical Sciences
Ed. G.T. Tseng, *et al*, American Astronautical Society, P.O. Box 28310, San Diego, California 92128, 1984, 1370pp, h/c $120; s/c $90; Microfiche Suppl. $40.

This book, in two parts plus a microfiche supplement, presents the proceedings of the annual AAS/AIAA astrodynamics conference held in Lake Placid, New York, 22-25 August 1983. Session topics included attitude dynamics, mission analysis for planetary exploration, orbit determination, attitude determination and control, flexible spacecraft dynamics and control, celestial mechanics, mission analysis for Earth orbiting applications, orbit transfer and reentry, and special sessions on autonomous navigation and the Space Telescope.

Engineering Sciences and Mechanics, Parts I and II, Vol. 50 Advances.
Ed. Han-Min Hsia *et al*, Univelt Inc., P.O. Box 28130, San Diego, California 92128, 1537pp, 1984, h/c $120.

This two volume set, Vol. 50 of the AAS Advances in the Astronautical Sciences series, is the product of an international symposium held in Taiwan under the sponsorship of the National Cheng-Kung University and the American Astronautical Society. About 100 papers are published, covering such areas as measurements and control, chemical engineering, aerospace science and technology, computer applications, dynamics and control, composites and other materials. Since the total quantity of papers presented would have brought about volumes of 2000pp or more, considerable editing and synthesising has been made.

Dr. H. Jacobs has advised us that an error occurred in the Book Notices section of *Spaceflight*, December 1984. The write-up on Astrodynamics 1983, Parts I and II does not apply to that 2-part volume (Vol. 54 Advances) but to Volume 50 Advances.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

EDITORIAL

Continued from p.193

the need and some solutions are so clearly identifiable and the public wish to put matters right so apparent, the question remains as to why steps are so tardy, so feeble and so ineffective.

There is little doubt that adequate solutions will stem from the thrust of space developments and not from any other areas of human endeavour e.g. the growth of agriculture is more likely than not to be met by a growth in human population. World birth control seems very unlikely; while the continuance of mismanagement and wastage in resources, apparent in every quarter of the globe, shows that there is little chance of any house being put in order either by governments, international agencies or anyone else.

We are left with only one hope, i.e. that our space capability will develop to such an extent that it will, eventually, provide the sinews to resolve these difficulties. Each space advance chips away at the problem. If space developments can be fostered and nurtured and left to grow into the major tools then really there is no doubt that, both with the Earth and with other worlds, Global Management - for real - will inevitably emerge.

The time must come when this message will percolate to the extent that all those good people who now give so freely, e.g. to try to alleviate world famine problems, become, at last, aware of the fact that these problems are not really being solved. People of good intent will come to demand, one day, that such problems be finally resolved.

This is a subject to which we will turn, increasingly, as the years roll by, for events will prove it vital not only to use space activities to sustain our civilisation on Earth but to make maximum use of the resources of other worlds.

If we do not opt for the peaceful exploitation of space, what else is left, apart from global destruction?

spaceflight

Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01–735 3160.

NOTICES OF MEETINGS

Lecture
Theme: **PLASMA PHYSICS IN SPACE**
by Dr. D.A. Bryant
Rutherford Appleton Laboratory

Results from the three-satellite AMPTE mission, launched in August 1984 to explore by revolutionary new techniques the interaction of the solar wind with the Earth's magnetosphere and the comet-like behaviour of injected plasma clouds, will be discussed.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on **1 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture
Theme: **COHERENT LIGHT FROM SUPERNOVAE**
By A.T. Lawton
President of the Society

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **15 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

One-day Forum
To be held in the Society's Conference Room, 27/29 South Lambeth Rd, London, SW8 1SZ on **Saturday, 1 June 1985**, 10.00 a.m. to 5.00 p.m.

Topic: **THE SOVIET SPACE PROGRAMME**

Subjects will include :

History of the USSR Lunar Programme

Cosmonaut Update

Soviet EVA Experiments

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

Lecture
Title: **SATELLITE INSURANCE**
By R Buckland

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **12 June 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time, enclosing a stamped addressed envelope.

Lecture
Theme: **METEORITES: SURVIVORS OF THE EARLY SOLAR SYSTEM**
By Dr. A.L. Graham
Dept. of Mineralogy, British Museum

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **18 September 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

36th IAF Congress
The 36th Congress of the International Astronautical Federation will be held in Stockholm, Sweden on **7-12 October 1985**. The theme is:

PEACEFUL SPACE AND GLOBAL PROBLEMS OF MANKIND

Members of the Society wishing to present papers are asked to notify Dr. L.R. Shepherd, Chairman of the BIS International Liaison Committee at Society HQ as soon as possible. Members wishing to present papers to the IAF Student Conference must submit them through the Society.

Lecture
Theme: **THE OORT COMETARY CLOUD: PROBLEMS AND PERSPECTIVES**
By Dr. M.E. Bailey
University of Manchester

The physical structures of comets, observations bearing on their sites of formation and the usual steady-state 'Oort Cloud' theory of cometary origins will be reviewed. Several apparently severe problems for this general picture will then be described, emphasising that the 'Solar System vs Interstellar' debate continues and the validity of the steady-state Solar System model remains unresolved.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on **30 October 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:
1 May 1985
15 May 1985
12 Jun 1985

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published by the British Interplanetary Society Ltd., (No. 402498). Registered Office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

spaceflight

Внеочередной

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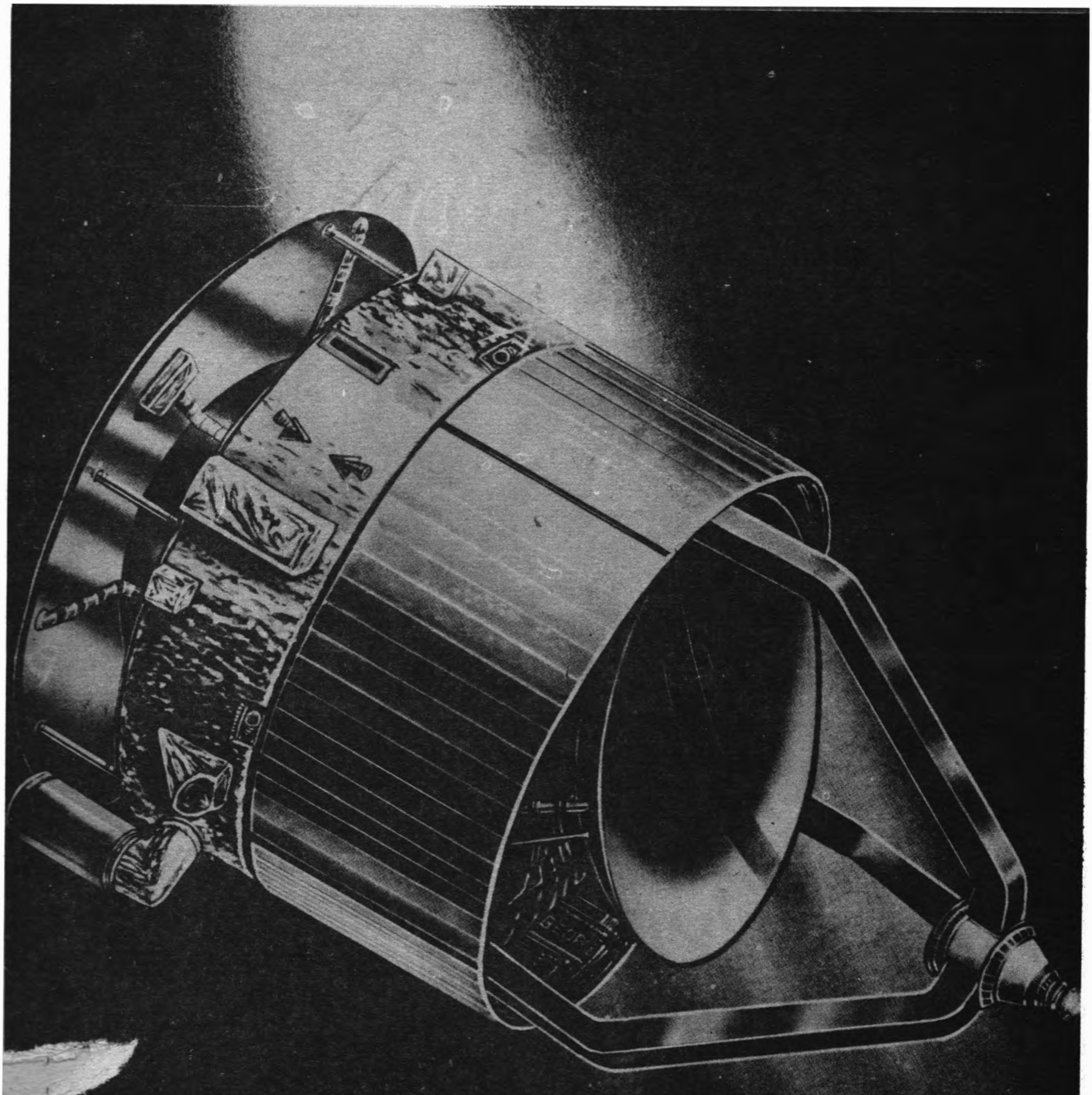
(спейсфлайт)
По подписке 1985 г.



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MEET THE UK ASTRONAUTS

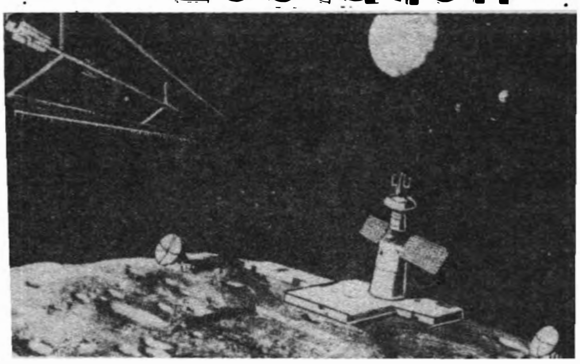
The first Briton to travel into space is due to go aloft in 1986 aboard the Space Shuttle with a UK Skynet communications satellite. All four of the candidates in training - Nigel Wood, Richard Farrimond, Peter Longhurst and Chris Holmes - will be Guests of Honour at a special dinner to be held at Society headquarters on the evening of Friday, 21 June 1985.

This is a unique opportunity to meet the men who will be part of space history. There are only a limited number of places available, so early application is essential. The cost (including sherry, 4-course meal and a half bottle of wine) is £18 per person.

Registration forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Top left: Nigel Wood (RAF), *top right:* Richard Farrimond (Army); *bottom left:* Peter Longhurst (RN); *bottom right:* Chris Holmes (MoD).

Space Education



The first of this year's *Space Education* issues includes a range of articles on astronautics and astronomy. Two cover infrared and X-ray astronomy from above the atmosphere, emphasising the enormous strides achieved since the beginning of the Space Age. The Voyager encounter with Neptune in August 1989, which will revolutionise our knowledge about the planet, is reviewed in a NASA/JPL article. Robert Frisbee contributes the first part of a comprehensive basic survey of rocket propulsion systems while Robert Mackenzie completes his description of an exciting branch of astronomy with 'Meteor Astronomy: Comets, Minor Planets and Meteor Streams.'

Tom Patrick, of the Mullard Space Science Laboratory, provides an insight into the structural design of satellites, and Robert Christy, who contributes the regular 'Satellite Digest' to *Spaceflight*, considers the geostationary orbit in 'An Orbital Guide.' Roger Smith discusses the use of Landsat imagery in the teaching of geography and Paul Maley describes how to employ video techniques in amateur astronomy.

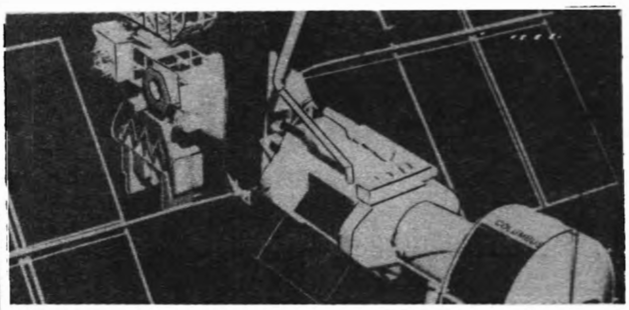
Copies of the May *Space Education* can be ordered for just £2 ($4) each, post free.

SPACE STATION APPLICATIONS

The second part of the successful Symposium on 'Space Station Plans' will follow on **25 September 1985.** The theme of **Space Station Applications** will consider such topics as Earth observations, astronomical research, materials science and engineering, medical research, communications and its use as a staging and servicing post for payloads bound for higher orbits.

The Society has long advocated permanently manned space stations so this Symposium is an important event in the space calendar. A panel of international speakers will present a series of papers to update present thinking on one of today's major space topics.

Offers of Papers are invited. Further information and Registration forms may be obtained from the Executive Secretary.



SYMPOSIUM

A two-day Symposium on the theme of **Towards Columbus and the Space Station** will be held in Bonn/Bad, Godesburg, Stadthalle, W. Germany on **3-4 October 1985,** organised by the DGLR and co-sponsored by the BIS, AAS, AIAA, AAAF and AIDAA.

Further information and registration forms will be available from the Executive Secretary in due course. Please advise BIS Headquarters as soon as possible if you plan to attend.

ВНИМАНИЮ ПОДПИСЧИКОВ!

В связи с задержкой поступления из-за границы журнала "Космические полеты" № 5 высылаем Вам последующие номера.

spaceflight

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THE EXPLORATION OF SPACE

The space potential was first widely recognised following World War 2, though it took the bleeping of Sputnik 1 to bring home the realities to many, initiating early attempts to explore space using purely scientific and relatively simple payloads. Those days were heady, rather like America must have seemed to the Pilgrim Fathers: huge, open and free - for space was vast and no-one knew what to do with it. Now, space presents a number of faces, each of which attracts adherents. The principal areas which now recognised are as below:

Scientific Exploration

This is the original and earliest face of all. It provided an immense fund both of new knowledge and the answers to earlier puzzles. It also introduced a host of new puzzles, most of which are still unanswered. Scientific work does not usually earn money on a commercial basis and, as a consequence, is supported financially by government or other controlling panels. Much is at a minimum level with subsequent changes cut to the bare minimum. Of the Viking Mars explorers, for example, Carl Sagan once bitterly remarked 'If the Finance Committee had voted an extra 30 dollars we could have carried an automobile headlamp and seen whether tnere was nightlife on Mars.' He was not joking, merely commenting on relative parsimony.

Communications and Earth Resources

These followed the pioneering path of scientific satellites but were to be operated on a strictly commercial basis. This has proved especially true of communications, where the field is still developing and where commercial industries are investing funds on an ever-increasing scale. Most expect the reliability of satellites and launchers to improve, operating costs to drop and profits rise. These profits will swell the income of supporting companies and enable a percentage to be put in areas presently heavily or exclusively government-funded, particularly if profits so invested were open to concessions.

This situation will undoubtedly develop more rapidly in the US where there is more funding available, greater freedom of operation and a greater spirit of adventure and willingness to take large capital risks. Several US companies are already investigating purely commercial rocket launchers, including looking for launch sites, so it may be only a matter of time before take-off.

Manned Space Flight

In some quarters this has been opposed on the grounds that money used on such projects is money diverted and wasted. If such flights were purely politically motivated and simply a case of East *v* West, such arguments might be justified. But, despite his need to be oxygenated, fed and watered regularly and also returned to Earth at periodic intervals, Man's presence in space cannot only be economically justified but seen to be absolutely

Continued on p.288

COVER

The next issue of *Spaceflight* will contain an article by H.J.P. Arnold of Space Frontiers Ltd. on the likely visibility of Halley's comet and how to photograph it. The cover picture shows the European Giotto probe, to be launched in early July by Ariane from South America, approaching Halley's nucleus.

Space Frontiers Ltd.

Covering Space

Sir, I am afraid your Editorial's lament over media disinterest in space (*Spaceflight*, February, p.49) is echoed on this side of the Atlantic. With a few notable exceptions, media coverage of space events over here is represented by some very uneducated and, worse, unenthusiastic people. Nowadays, TV coverage of Shuttle launches barely exists, restricting itself to a few seconds of the launch. Unlike TV, radio has provided quite good coverage of Shuttle landings.

It is unfortunate that it is the setbacks that gain the most attention. I believe that, in Arthur Clarke's words, 'when the first real space products start hitting the market, when people start seeing things that are actually *made in space*,' we will see a sudden media turnaround, and public enthusiasm for space projects will increase.

JOHN FADUM
Florida

A Change of Tactics

Sir, Your February 1985 issue of *Spaceflight* raised the editorial question 'Where Oh Where Have the Media Gone?' The mass media and the general public are more interested in what space hardware can create in new social values, human drama, and new philosophical possibilities. The public doesn't understand or care to know all about the nuts and bolts of the situation.

The space community has been too modest in telling the public *why* they are doing what they are doing - the philosophical basis. Of the three space pioneer giants, only Tsiolkovsky publicly told of the need to achieve interstellar life seeding as a means for human survival. Goddard did so in a paper that he kept from publication until after his death. Oberth did not make his statement of philosophy about space and human survival, indeed the survival of life, until the last two sentences of his book *Man Into Space*, where he stated the goal of space was to '.. make available for life every place where life is possible. To make inhabitable all worlds as yet uninhabitable, and all life purposeful.'

WILLIAM SAUBER
Michigan, USA

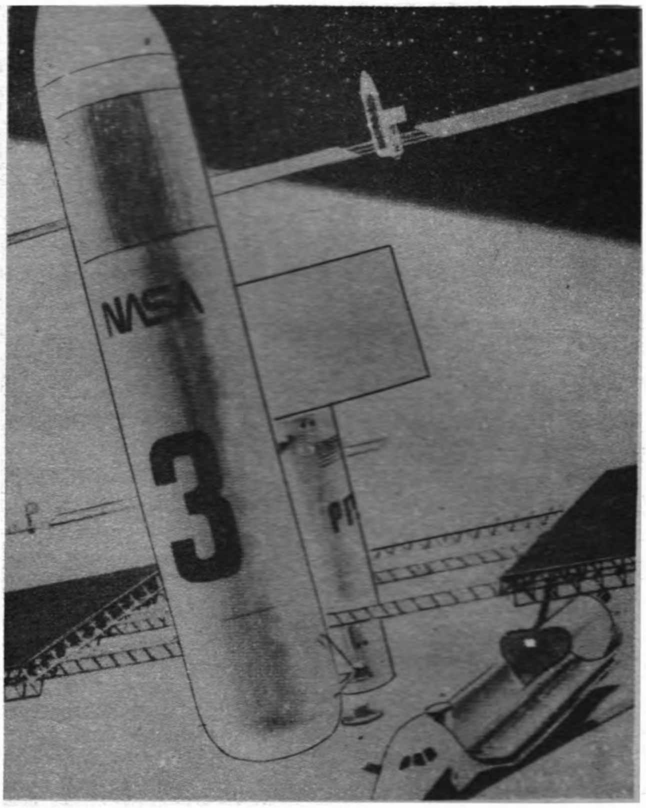
External Tanks/Space Station

Sir, What would be the cost of ferrying a Shuttle External Tank to the Space Station orbit? I was thinking of Skylab's magnificent 'workshop' which began as a Saturn 5 third stage tank. It was converted on the ground but the early plans would have adopted the spent upper stage. An External Tank's bracing looks complicated but surely an entry is possible? The External Tanks' strong-points would add stability and rigidity to the spindly Power Tower concept for NASA's Space Station.

N. KELLY
Liverpool

Dr. R.C. Parkinson, Study Manager of Space Station Studies at British Aerospace, replies:

In the course of the last two years I think I have seen every possible configuration for the Space Station, with and without External Tanks, and one from Rockwell which would have used a fifth or sixth Shuttle Orbiter structure, less wings, plus the External Tank as the 'core.' As the



Space Station concepts using Shuttle External Tanks have been proposed on several occasions. *NASA*

studies have continued at NASA, certain critical features have become apparent. One feature of key importance appears to be the effects of air drag and gravity gradient torques on the propulsive requirements of the Station with its very large solar arrays. NASA will have to provide continuous supplies of propellant to keep the Space Station in orbit, which not only adds to the logistics mass but makes the Space Station environment 'dirty.' As a consequence, NASA has not only baselined the gravity gradient stabilised 'Power Tower' but also moved the orbital altitude to 500 km. This is actually above the 'full load' ceiling of the Shuttle, which will need an OMS 'kit' to lift it higher. Lifting a relatively heavy External Tank would demand still more propellant, which would limit the Shuttle's useful load severely.

Skylab experience suggests that modifying an existing structure like the External Tank is not really cheaper than building from scratch. For reasons such as this, I suspect, the balance has tipped away from External Tank stations. However, the Phase B contractors are still being expected to look at the whole architecture, so the NASA picture is not yet the final word.

A Reply to *Scoops*

Sir, This is in response to the *Scoops* question raised in last month's 'From the Secretary's Desk.' The 24 March 1934 issue of *Scoops* featured an article headed 'Shall we ever travel to the Planets' (with the question mark omitted), followed by the statement 'Sir James Jeans declares that we must expect to find that all the planets, except our World, are dead worlds.'

What followed was evidently an editorial contribution on the subject, based on a series of lectures recently

given by Jeans to members of the Royal Institution. It concerned not the problems associated with making an interplanetary journey but the unfavourable conditions that would be encountered on the Moon and the planets, the implication being that there was not much point going there anyway.

I was invited to reply to this article, for publication in the next issue, dated 31 March. It was entitled 'We SHALL travel to the Planets.' I took the opportunity of discussing the problems of making such a journey. Incidentally, there was further discussion in a subsequent *Scoops* article that appeared in the 9 June 1934 issue, entitled 'Rocketing Into Space.'

P.E. CLEATOR
Merseyside

Voskhod Landing System

Sir, In a recent account [1] of the Soviet Voskhod programme, the soft-landing technique used on these spacecraft was discussed. The Soviets have recently confirmed this speculation [2]. The diagrams included here are redrawn from the Soviet original.

R.F. GIBBONS
Derbyshire

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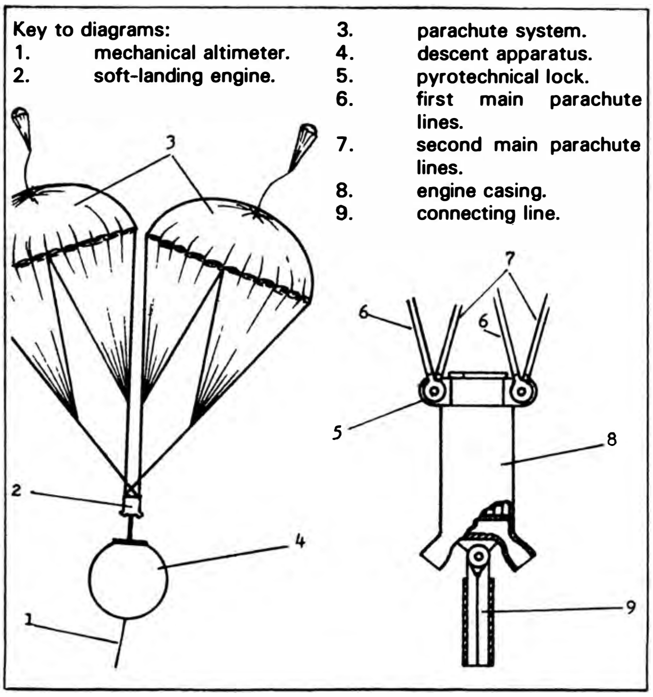
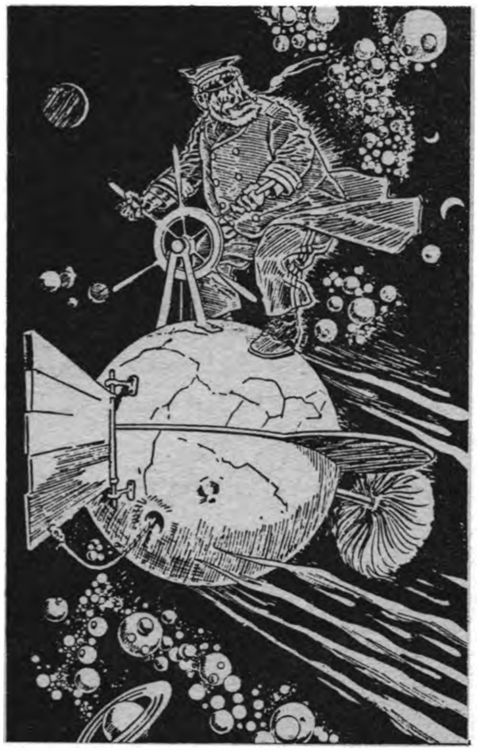
1. R.F. Gibbons and P.S. Clark, 'The Evolution of the Vostok and Voskhod Programmes,' *JBIS*, **38**, 3-10, (1985).
2. V.N. Bobkov and V.S. Syromyatnikov, *Kosmik Korabli*, Znanie, 21-22, (1984).



A Very Special Spaceship

Sir, Knowing the Executive Secretary's propensity for matters ecclesiastical - witness his endeavours to secure a sainthood - the rocket-type vehicle depicted in "Captain Stallfield's Visit to Heaven" (Mark Twain 1909) seems to meet his requirements on many counts. On page 19, for example, when the Captain first tried to find someone in Heaven that he knew he was told "they were out of acquantainces of mine just then" - a situation which he also might have to face in due course.

The journey, too, might prove of great interest, bearing in mind his fascination for comets for the Captain notes



"I've seen comets out there that couldn't even lay down inside the *orbits* of our noblest comets, without their tails hanging over."

A. NON

The Executive Secretary responds:

The craft shown is an early version of a shuttle capable of making the journey from Earth to Heaven, or Hell, and between the two. Mr. Non may be distressed to know that it cannot land in Purgatory.

'Ask, and Ye Shall Receive'

Sir, A friend of mine in Oregon, R.H. Carlson, who is a member of your Society, told me that the British Interplanetary Society needed a copy of my book, *Moon Rocks*. When the BIS calls, who can refuse? I am sending herewith a copy of that book, together with two later ones on the subject of space travel, *The Search for Life on Mars* and *Imaging Saturn*.

HENRY S.F. COOPER
New York

Received with thanks! -Ed.

SNIPPETS

Commercial Space Advertising

Sir, Referring to 'Commercialising Space' in January's *Spaceflight*, there is not, and probably will never be, any need for multi-nationals to advertise in this manner. There are other media such as international sport where such businesses can advertise without doing any harm.

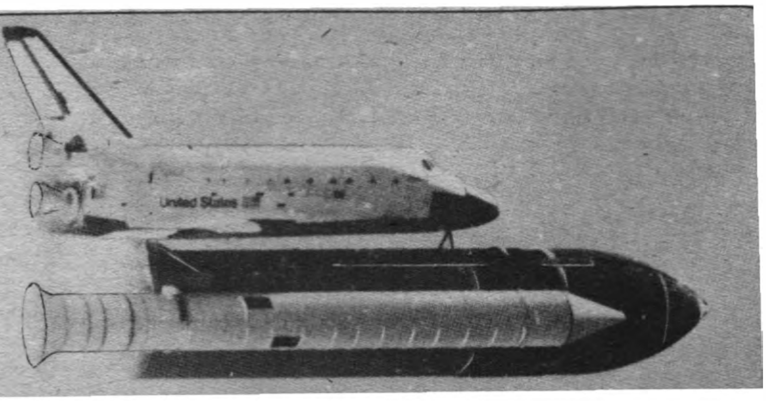
N.R. TOMKINS.
W. Midlands

The Best There Is

Sir, Your book, *The Eagle Has Wings*, is the best I've seen on the history of the Mercury, Gemini, and Apollo programmes. I am an aerospace engineer at the Marshall Space Flight Center in Huntsville and currently work on the Space Shuttle; I previously worked on Apollo and Gemini, as well as the Skylab programme.

GERALD R. DIXON
Alabama, USA

SPACE REPORT



A monthly review of space news and events

SPACE SHUTTLE

SHUTTLE CREWS

The cancellation of Shuttle mission 51E in early March because of problems with the TDRS payload forced the reshuffling of flight crew assignments. Six of the 51E team, Karol Bobko, Donald Williams, Rhea Seddon, Jeffrey Hoffman, David Griggs and Jake Garn, moved over to 51D, while Frenchman Patrick Baudry was slotted into 51G in June. Charles Walker is the only survivor of the original 51D crew, flying with McDonnell-Douglas' electrophoresis experiment, while Dan Brandenstein, John Creighton, Shannon Lucid, John Fabian and Steven Nagel awaited reasignment.

Concerning Baudry's move, NASA and the French Space Agency agreed that the 51G mission is the earliest opportunity with adequate middeck experiment stowage for the French medical experiments. An additional advantage is the seven-day duration of that mission, which will allow greater data collection.

NASA will provide an additional opportunity to the Hughes company for the flight of one of their payload specialists to make up for the lost opportunity on 51D. The fluid transfer experiments that Hughes' specialists will perform are designed to help satellite design work. As of mid-March, Hughes had to inform NASA whether John Konrad or Gregory Jarvis will fly on the 51I flight, now scheduled for early August.

In announcing the changes on 6 March, it was indicated that a primary factor was the preservation of this year's flight schedule and crew training schedule. It is necessary to fly Bobko's crew now in order to preserve subsequent training schedules for the 51J military mission (the first flight of *Atlantis*). This reassignment is consistent with a NASA policy of separating crew *flight* assignments from *payload* crew assignments except for Spacelab and military missions where substantial crew/payload interaction is required.

SHUTTLE ENGINE TESTS

The B-2 Space Shuttle Main Engine test stand at the National Space Technology Laboratory in Mississippi, originally used in the 1960's to flight certify the first stage of the Saturn 5 and more recently to certify the Shuttle's main propulsion system in a series of three-engine 'cluster' firings, will be modified to allow a third position to static fire the Shuttle engines individually, writes Nicholas Steggall. This modification contract, valued at $2.4 million, will take one year to complete.

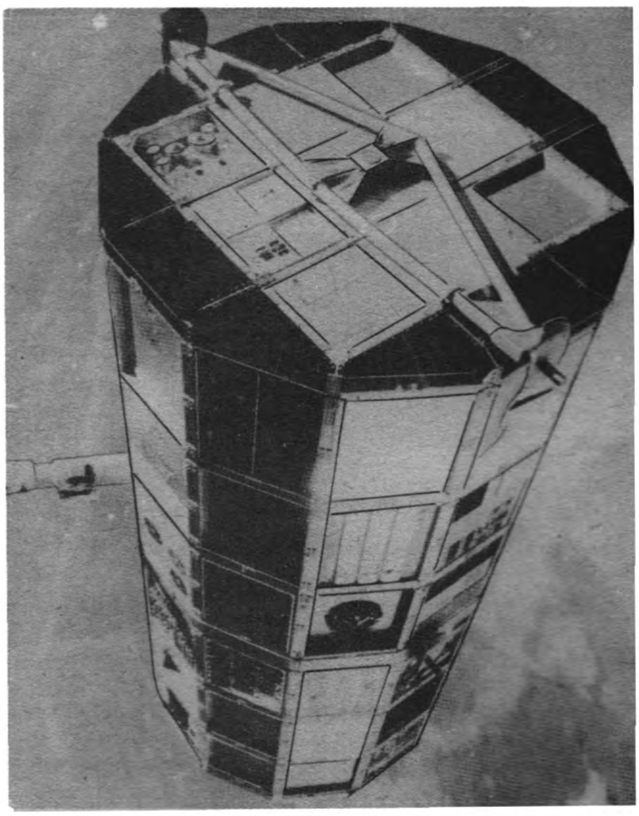
NSTL began Shuttle engine testing in June 1975 using the A-1 and A-2 test stands for single engine runs of flight and non-flight engines. The B-2 stand will be modified so that it can be returned to the cluster configuration if required. It will support the projected increases in main engine test requirements, including increased turbopump production rates and will be used initially to try out new and overhauled turbopumps.

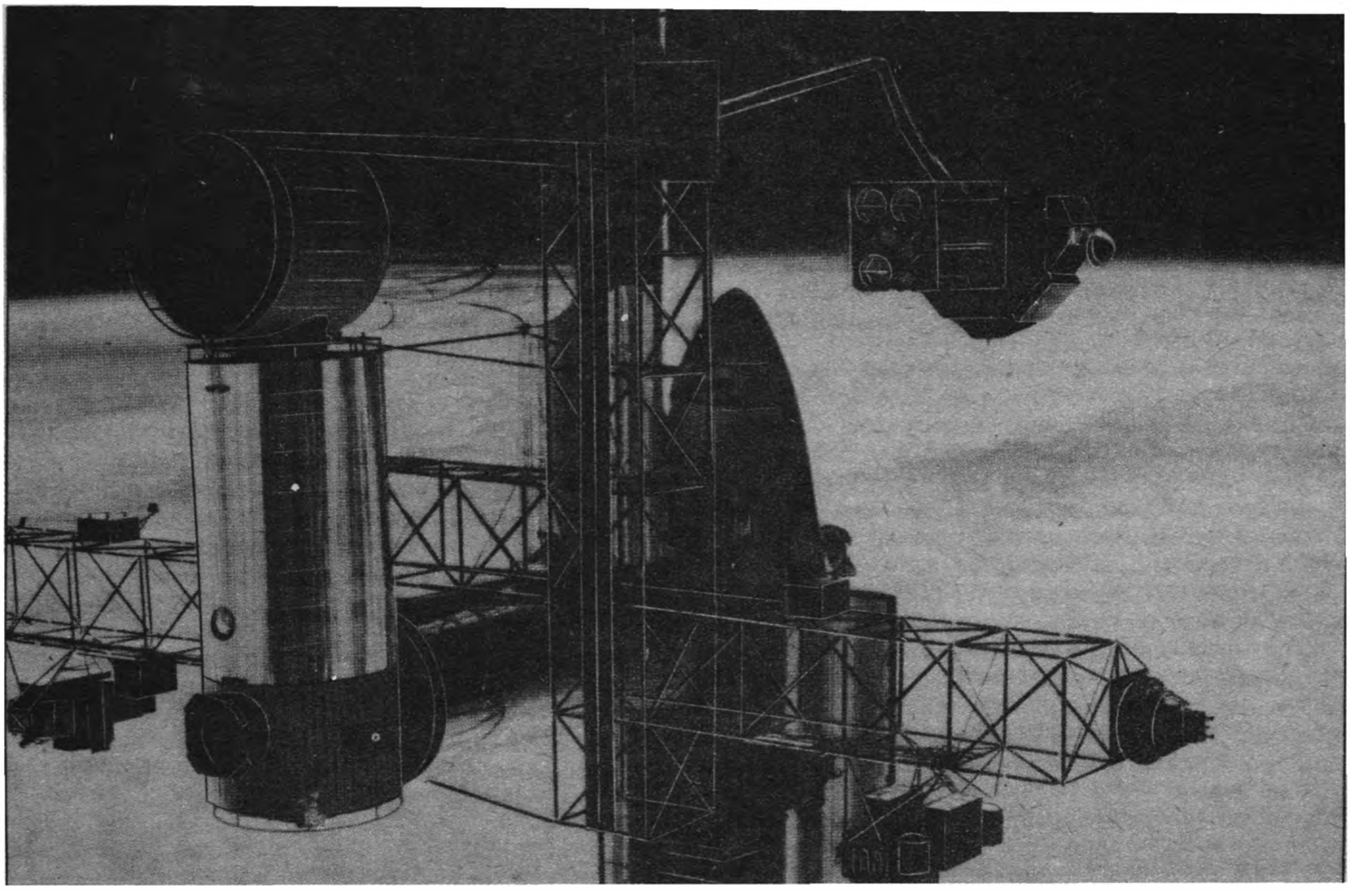
SPACE SUIT STUDIES

McDonnell Douglas engineers are studying the type of space suit that astronauts will need in the 1990's to assemble and service NASA's Space Station, writes Gerald Borrowman.

The Johnson Space Center awarded the company a $700,000 contract to conduct the 11 month study as part of NASA's plan to build the permanent station. Once

Cancellation of the Shuttle 51E mission on 1 March means that the Long Duration Exposure Facility, released from 41C in April 1984, will not be retrieved until later this year instead of on Mission 51D at the end of March. This was because the Anik C communications satellite from 51E was moved to 51D, its handling cradling taking up too much room for the LDEF to fit in. *NASA*





NASA awarded parallel contracts to Boeing and Martin-Marietta in March for the definition and preliminary design of Space Station pressurised common modules for use as laboratories, living areas and logistic transport. The picture shows a Shuttle docked to the modules and a satellite carried by an Orbital Maneuvering Vehicle at upper right. *Boeing*

the study team has defined the range of activities the astronauts will undertake, it will suggest how the suit and supporting equipment can be improved. Improvements might also be made to the Manned Maneuvering Unit, which can fly only a few hundred feet at present because of fuel restrictions. The Space Station itself will be about 400 ft (122 m) long.

One proposed improvement would allow astronauts to suit up and leave the station without lengthy depressurisation periods. At present, Shuttle crews must lower the air pressure in the cabin to match the lower pressure in the suit, a process that can take up to 12 hours. Other changes could include adding communications equipment and recirculating air to prevent vented carbon dioxide from contaminating other parts of the station. To increase efficiency, the MMU and suit functions might be controlled by spoken commands.

One problem now faced by astronauts is the cumbersome task of keeping track of procedures during a spacewalk. For example, when the Solar Max satellite was repaired in April 1984, typed instructions were attached to the arm of the suit. On the next-generation suit, such instructions could be held in a computer and transmitted to a 2.5 cm TV screen in the suit's helmet. Another possibility is to equip the helmet with a see-through 'head-up' display (similar to those used by the Shuttle pilots on their foward windows) to project instructions on to the inside of the visor.

SMALL GAS SATELLITES

NASA plans to deploy two small experimental satellites from Get Away Special (GAS) containers mounted in the cargo bay of Orbiter *Challenger* during 51B/Spacelab 3 mission in late April/early May.

The Global Low Orbiting Message Relay Satellite (GLOMR) and Northern Utah Satellite (NUSAT) will be deployed for $10,000 each under the GAS programme, the first attempt at launching satellites from GAS.

The canisters have been upgraded with ejection systems for the mission, according to Clarke Prouty, technical liaison officer for the GAS programme at Goddard. 'We also developed a motorised door for the can similar to the one first flown on the seventh Shuttle mission, which allowed the GAS payload to be exposed to space. The new design is called the Full Diameter Motorized Door Assembly.' Prouty said that the FDMDA enables the canister to be insulated before and after the satellite is deployed and it provides a means for retaining the satellite in case of a malfunction. He explained that the spacecraft separation system used in the Delta rocket had been adapted for these ejection systems.

GLOMR is a data relay communication satellite and is expected to remain in orbit for about one year. NUSAT is an air traffic control radar system calibrator. It will measure antenna patterns for ground-based radars operated in the United States and in member countries of the International Civil Aviation Organization. It has an expected lifetime of about six months and was designed, built and tested by Weber State College in Utah, in coordination with the Federal Aviation Administration.

The two were to be launched, NUSAF first, at the end of the Spacelab 3 science activities on the sixth day of the seven-day 51B mission. The GAS programme is available to anyone who wishes to fly a small experiment aboard the Shuttle. Space is made available in 0.07 and 0.14 m^3 containers and experiments must be of a scientific research and development nature. Twenty-nine canisters had flown up to the end of 51C in January.

PLUTO/CHARON ECLIPSES

A rare alignment of Pluto and its only known satellite, Charon, is giving astronomers a new tool to study the two bodies. Astronomers are observing Charon as it alternately moves in front of and then behind Pluto in a rare series of eclipses that occur every 124 years, or twice in each orbit of the Sun.

Each time Charon passes between Pluto and the Earth a portion of the surface of Pluto is blocked from view, resulting in a dimming of the combined light. When Charon moves *behind* Pluto their roles are reversed. Measurements of the times, durations and changes in brightness will allow the masses, diameters and densities of both to be calculated.

A more accurate estimate of their densities would allow models of what the planet and its satellite are made of to be developed. Estimates of Pluto's density now have an uncertainty of 50% which is not accurate enough to derive information on its composition. The density is thought to be about that of water, which would make it the lowest-density planet known with a solid surface.

The new measurements indicate that the combined brightness diminishes by 4%. The dimming lasts for about two hours and is superimposed on a 30% brightness change that occurs over a 6.4 day period. The longer change in brightness happens because one hemisphere of Pluto is 30% brighter than the other.

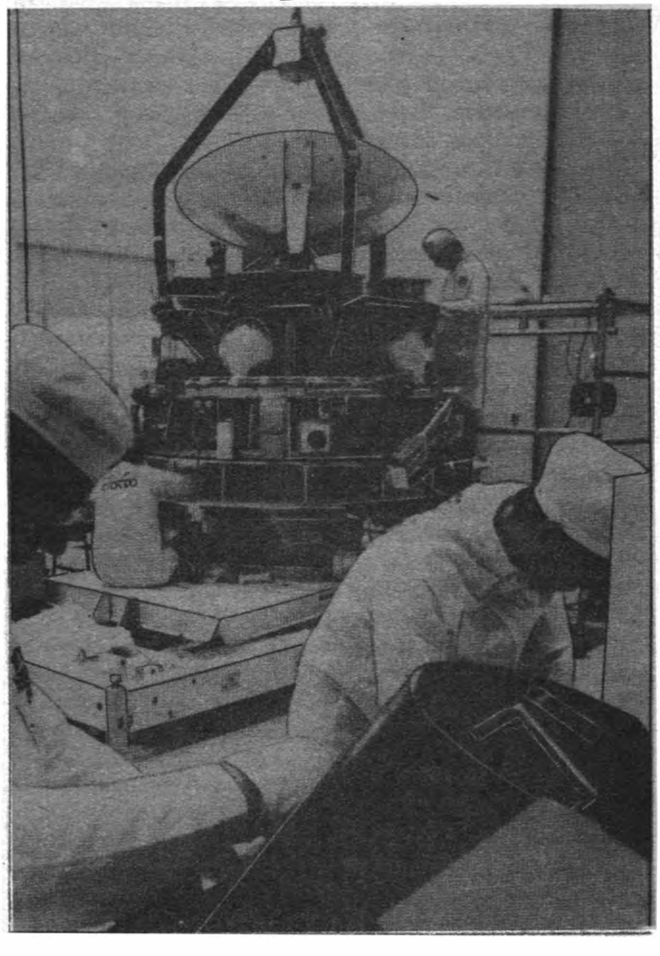
Very little is known about Pluto and even less about Charon. No one knew, for example, when or even if the five year long series of eclipses would begin. (This is the first opportunity to observe the eclipse series since the planet's discovery in February 1930.) So that they would not miss any of the earliest events, an observing network was established made up of astronomers at McDonald Observatory in Texas, the University of Arizona observatories, Palomar Observatory in California and Mauna Kea Observatory in Hawaii.

The first to see and measure an eclipse of Pluto by Charon was Dr. Edward Tedesco of JPL, while observing with Dr. Bonnie Buratti, also of JPL, at Palomar on 16 January. On 17 February Richard Binzel observed another eclipse from the University of Texas' McDonald Observatory. Dr. D.J. Tholen observed yet a third eclipse on 20 February from the Mauna Kea Observatory.

Charon was discovered in 1978, its orbital motion around Pluto showing that the parent body is tipped on its side in much the same way as Uranus, so that it alternately points its north and then its south pole towards the Sun.

Pluto circles the Sun in a highly elliptical orbit. It has been inside Neptune's path since 1979 and will remain there until 1999. Its average distance from the Sun is 6,000 million km, almost 40 times greater than Earth's. Since it circles the Sun only once in 248 years, Pluto has yet to complete an orbit since discovery.

Giotto is prepared for final electrical testing at the Interspace facility in Toulouse, France. In the foreground is the Starmapper, a key element of Giotto's attitude measurement system made in Holland. Its main use is to detect the position of the Earth on the sky during the journey. The data automatically cause the despun dish antenna to remain Earth-pointing for data transmission. It also detects stars to determine Giotto's attitude. *BAe*



AXAF INVESTIGATIONS

NASA announced in early March the instruments to be flown on the Advanced X-ray Astrophysics Facility. AXAF is an X-ray observatory that will operate in low-Earth orbit for at least 15 years. The basic observatory consists of a 1.2 m diameter, 10 m focal length X-ray telescope housed within a spacecraft carrying an array of selected instruments and providing power, precise pointing and data transmission. AXAF will make detailed observations of the X-ray emissions from cosmic sources ranging from nearby stars to distant quasars.

Construction could begin as early as 1987-1988 with launch approximately five years later. In orbit, AXAF will join the Hubble Space Telescope, to be launched in 1986, and the Gamma Ray Observatory, planned for 1988. These three, together with the later launch of the planned Space Infrared Telescope Facility, will allow simultaneous observations of cosmic sources over infrared, visible, ultraviolet, X-ray and gamma ray wavelengths.

The AXAF investigators fall into three categories: Instrument Principal Investigators, with the responsibility for design and fabrication of scientific instrumentation in the telescope's focal plane; Interdisciplinary Scientists, who provide scientific expertise from both X-ray astrophysics and other fields of astronomy; and a Telescope Scientist, who will provide the scientific and technical expertise essential to the fabrication of the X-ray telescope.

The Instrument Principal Investigators are:

Dr. Gordon Garmire, Pennsylvania State University, 'Charged Coupled Device Imaging Spectroscopy.'

Dr. Steven Murray, Smithsonian Astrophysical Observatory, 'High Resolution Camera.'

Dr. Stephen Holt, Goddard Space Flight Center, 'X-Ray Spectroscopy Investigation for the AXAF.'

Dr. Claude Canizares, Massachusetts Institute of Technology, 'High Resolution X-Ray Spectroscopy Using AXAF.'

Dr. Albert Brinkman, University of Utrecht, Netherlands, 'High Throughput Transmission Grating for Cosmic X-Ray Spectroscopy.'

The Interdisciplinary Scientists are:

Dr. Riccardo Giacconi, Space Telescope Science Institute, 'Advanced X-Ray Astrophysics Facility Mission (AXAF).'

Dr. Jeffrey Linsky, National Bureau of Standards, 'The Coronal Structures of Selected Cool Stars and Close Binary Systems.'

Dr. Richard Mushotzky, Goddard Space Flight Center, 'A Program to Measure the Mass of Galaxies and Clusters of Galaxies with AXAF.'

Dr. Andrew Wilson, University of Maryland, 'Studies of Radio Jets and the Narrow Line Regions of Active Galaxies with AXAF.'

Dr. Andrew Fabian, Cambridge University, United Kingdom (a former member of the Society's Council), 'Cooling Flows in Clusters and Galaxies.'

The Telescope Scientist is Dr. Leon Van Speybroeck of the Smithsonian Astrophysical Observatory.

The investigators will be appointed members of the AXAF Science Working Group, which will provide scientific and technical guidance to the project from initial design to in-orbit operation. Each will receive a specific period to use the telescope during the first 30 months after it is declared operational.

HALLEY IN INFRARED

British astronomers observing with the United Kingdom Infrared Telescope (UKIRT) at Mauna Kea in Hawaii have made the first infrared observation of Halley's comet. On the night of 20 December, the 3.8 m diameter mirror was pointed at the predicted path of the comet as part of a programme of cometary and asteroid observations.

Working at a wavelength of 1.25 microns (about twice the wavelength of red visible light), two separate observations of 25 minutes' duration were made, both of which showed a positive signal. The observation is not in itself a surprise since comets are often detected at these wavelengths; however, this detection has occurred some months earlier than might have been expected and is probably one of the faintest infrared detections of a comet ever made. It is also thought to be the first observation by British astronomers of Comet Halley since its last apparition in 1910.

Infrared emission from a comet arises in two ways, either through radiation from the Sun reflected by the nucleus and surrounding dust halo, or from the dust grains themselves that heat up as the comet approaches the Sun. This observation certainly represents infrared 'light' scattered from the Sun but it is interesting to speculate whether this is reflected by the solid nucleus alone or whether a dust halo has also contributed since it is very important for an understanding of cometary physics to know at what point in its orbit around the Sun a comet starts to emit a constant stream of dust (and gas) from its surface.

From this observation, it is possible to draw some tentative conclusions. If it is assumed that the observed signal was reflected only from the solid nucleus, then this nucleus would have to have a size of at least 12 km. Since this is larger than current estimates of the size of Halley, it is believed that some dust must already also be present to reflect the light from the Sun. This may help astronomers to determine what materials are present.

British astronomers have a considerable interest in this apparition of Halley: two of the experiments carried by Giotto were designed and built primarily by British researchers. The Dust Impact Detection System (Principal Investigator: Dr. Tony McDonnell, Space Sciences Laboratory, University of Kent) will measure the size of the minute dust grains - ultimately responsible for a comet's characteristic tail - as Giotto speeds through the cometary environment on its near collision course with the comet. Additionally, the Johnstone Plasma Analyser (Principal Investigator: Dr. Alan Johnstone, Mullard Space Science Laboratory, University College, London) will study the gas molecules emitted by the comet and their complex interaction with the solar wind.

SPACE VEHICLES

NEW TITAN MODEL

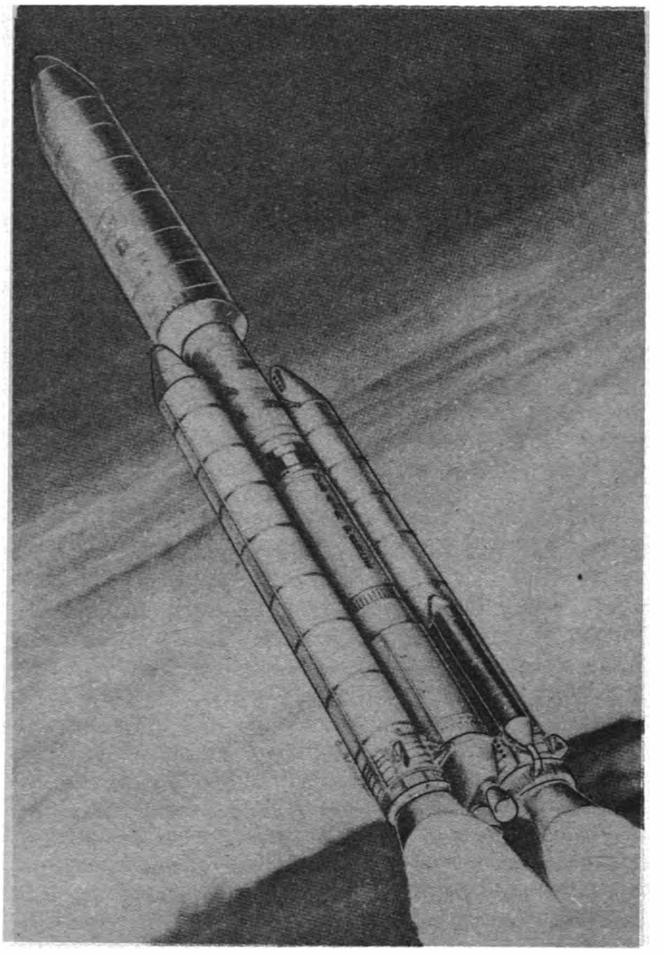
The Martin Marietta company was awarded an initial $5 million contract by the U.S. Air Force on 28 February to begin design work on the new Titan 3 variant, the 34D-7.

The U.S. Air Force has been concerned over the Shuttle's reliability and has long argued for a back-up capability to be available for launching 'national security' satellites. Martin-Marietta will build 10 Titan 34D-7s for launch at the rate of two per year beginning in late 1988. Each will be capable of placing a 4500 kg Shuttle-equivalent payload into geostationary orbit.

The present Titan 34D, which continues the basic Titan 3 design, has a longer stage 1 core and longer solid boosters than earlier models. The inaugural flight in October 1982 was the 118th success for the Titan family. The 34D-7 will use 7-segment boosters (hence the designation) and carry 5.1 m diameter payload firings.

The U.S. Air Force also intend to refurbish some of their old Titan 2 missiles for use as space launchers, reducing even further their reliance on the Space Shuttle.

The new Titan 34D-7 should be available in late 1988. Note the 7-segment boosters and wide fairing. *Martin Marietta*



NASA'S BUDGET

The Fiscal Year (FY) 1986 budget proposal sent to Congress in February by President Reagan requested $7,886 million for NASA.

'In a year of budgetary restraint, this is a modest, though forward-looking, budget,' said NASA Administrator James Beggs. 'Our objectives are to begin Space Station design and development in 1987 and to attain initial operational capability within a decade.'

The budget proposal would support the completion of definition studies and initial development of the Orbital Maneuvering Vehicle, a remotely-piloted, unmanned, reusable spacecraft to be used to extend the Shuttle's on-orbit operational range and capabilities.

The budget proposal also supports the remaining development, launch and operation of several major programmes in Space Science and Applications, including the Astro payload and Hubble Space Telescope. A set of three special telescopes, Astro will fly aboard the Shuttle in 1986. The Hubble Space Telescope will be launched in 1986.

Other Space Science and Applications included are the Galileo mission to Jupiter, scheduled to be launched in late spring 1986, and the Ulysses spacecraft to be launched towards Jupiter to study the Sun at high latitudes.

The FY 1986 budget proposal represents four major appropriations requests, according to Beggs.

First, a total of $2900 million is requested for research and development - this is about 36% of the total. The increase over the FY 1985 budget reflects the phasing in of previously approved Space Science and Applications programmes; the development of the Advanced Communications Technology Satellite; the initiation of the OMV; and the effort to promote the commercial use of space. Included in the research and development request is $230 million for the Space Station, which will enable NASA to 'make solid progress in advanced technology and the definition phase,' according to Beggs.

Second, $3500 million is proposed for space flight, control and data communications to support Shuttle production, operations and tracking and data acquisition.

Third, $149 million is proposed for construction of facilities. Under this portion of the budget request, NASA has requested $6.5 million to modify the Marshall Center's S-1C test stand for use as an Advanced Technology Engine Test Stand.

Finally, $1300 million is requested for research and programme management, representing a level of effort lower than last year's due to administrative economies and small inflationary price adjustments.

NEW TRANSMITTER ADVANCES

ESA have awarded Marconi Defence Systems a £260,000 contract to build seven advanced satellite communications transmitters to operate over the frequency band 1530 to 1555 MHz, writes Nicholas Steggall.

This order results from studies conducted into the possibilities presented by the latest L-band technology. Significant operational benefits could be gained by adopting such modular solid-state spacecraft transmitters. According to Inmarsat, this design would not only improve overall transponder reliability but also facilitate the use of multi-beam antennae to provide the flexible links needed for the fast-growing commercial maritime/mobile market.

MILESTONES

February 1985

25 The first Shuttle launch from Vandenberg will be flown by Robert Crippen (Commander), Guy Gardner (Pilot), Jerry Ross (Mission Specialist), Dale Gardner (MS) and Michael Mullane (MS). At least one USAF Payload Specialist will be added; the main payload will be the Teal Ruby satellite.

27 NASA delay Shuttle 51E to 7 Mar because of a battery problem in the TDRS satellite payload. Mission 51D will aim for 22 Mar.

28 Martin Marietta receives a $5 million USAF contract to design the Titan 34D-7 to act as a Shuttle-complementary vehicle.

March 1985

1 NASA cancels Shuttle 51E because of TDRS satellite problems. Anik C will fly on 51D later this month and the LDEF will not be retrieved until later.

5 Inmarsat is entering negotiations with British Aerospace to build three second-generation maritime communications satellites, with a possibility of six more.

5 The Ashford School for Girls wins the ITN/SSI Getaway Special space competition with their chemical garden proposal. It should be launched on the Shuttle next year.

6 Olof Lundberg, Director General of Inmarsat since its creation in 1979, is reappointed for a further six years, beginning next December.

6 The original crew of Shuttle 51D is replaced by Bobko, Williams, Seddon, Hoffman, Griggs, Walker and Garn, most of the cancelled 51E crew. Walker was on the original 51D and Baudry, from 51E, will now fly aboard 51G in June.

7 Boeing is selected for a $678,000 contract to study temperature control of Space Station compartments.

8 *Discovery's* payload doors are punctured in two places by a falling 'worker access platform.' Graphite epoxy patches are added and covered by thermal blanket material.

12 Geosat 1 is launched into 800 km, 108° orbit by Atlas E. The US Navy satellite will map the Earth's gravitational field.

16 The Vega 1 and 2 Soviet Venus/Halley craft are in good health, Novosti reports. The Venera 15 Venus radar mapper has now closed down but Venera 16 is still working.

18 Gyro control problems are encountered with Arabsat 1, launched by Ariane V12 on 8 Feb. and positioned at 19°E in geostationary orbit.

20 Dr. David Black of NASA Ames is named as Chief Scientist for the Office of Space Station at NASA HQ. His job is to ensure that the Station can accommodate the needs of scientific users.

26 NASA awards a 12-month contract to McDonnell Douglas to study the impact of the Space Station on the Kennedy Space Center.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

The Latest News from the European Space Agency, by Norman Longdon in Noordwijk, The Netherlands.

In the wake of Rome

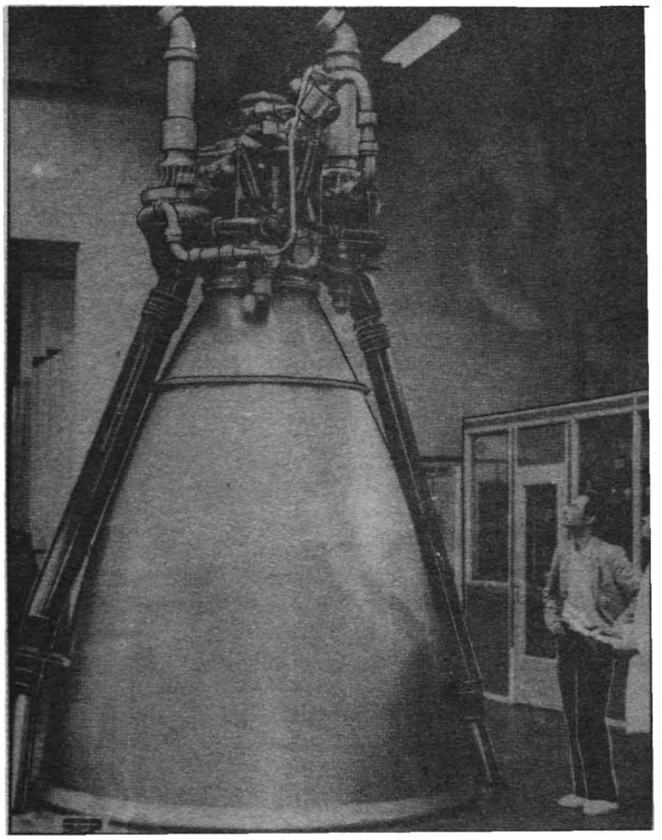
After the euphoria of the Rome conference in January, one might have expected a tightening of attitudes when delegates met to talk detailed money matters at the ESA Council meeting in February. Such was not the case; ESA faced the unusual problem of over-subscription for both the Columbus preparatory programme and the HM60 cryogenic engine for Ariane 5. Just as with individuals, so with Governments: when they put their hands in their pockets it is a real indication of intent.

As a semantic indication of the way ahead, the Spacelab Programme Board has been renamed the 'Columbus Programme Board.' There has been no lessening of the resolve that Europe should take a clear and firm stance in any negotiations on Space Station participation.

Ariane and the World Market

It takes little time for the general public to accept events as routine and Ariane launches are now a regular feature of the space scene. The V12 launch on 8 February 1985 deserves mention, however, because it was the first European launch of two non-European satellites. Both the Arabsat and Brasilsat communications satellites were successfully placed in geostationary transfer orbit. Nothing could illustrate the international nature of space more than the involvement of three continents in one launch.

ESA will develop the HM60 Large Cryogenic Engine for its future Ariane 5 launcher to produce a thrust of 1000 kN for about 600 seconds. *ESA*



Arabsat-F1, with a mass of 1215 kg at launch, is the first of three built for the 22 member states that belong to the Arabsat Satellite Communication Organisation (ASCO). Brasilsat-1 is the first of two for Embratel (Empresa Brasileira de Telecomunicacoes) and had a mass of 1140 kg.

Ariane Launch Schedule (as of 13 March)

Date	Flt.	Satellites
1985		
Jul	V14	Giotto
Aug	V15*	Spacenet-3 + ECS-3
Sept/Oct	V16	Intelsat-V F13
Nov/Dec	V17	Spot-1 + Viking
1986		
Jan	V18*	GSTAR-1 + Brasilsat-2
Feb	V19	Intelsat-V F14
Apr	V20	Intelsat-V F15 or TV-Sat
May	V21	Intelsat-V F15 or TV-Sat
Jun	V22	Aussat-3 + opportunity

* from second Ariane launch pad.

The Cornerstones

One outcome of the Ministers' Conference in Rome will be a drive to implement the four 'cornerstones' of the ESA space science programme.

In the Solar-Terrestrial Physics area this will mean seeking approval at the end of 1985 for two complementary missions, Soho and Cluster. The Solo mission would be a comprehensive, multidisciplinary solar-heliospheric observatory; Cluster, a combination of several small satellites as the name implies, would be a near-Earth plasma laboratory. Both could be part of the European contribution to the International Solar-Terrestrial Physics programme foreseen for the early 1990's.

A strategy for the planetary 'cornerstone' is being worked out within the ESA Long-Term Plan, but it seems likely that it will include the return to Earth of pristine material. One possibility being considered is a rendezvous with a comet to extract core material. This is an area in which there is very active NASA/ESA collaboration, and both Agencies are considering conducting a short technical study of the feasibility of using a Giotto-derived spacecraft for a comet coma sample return mission. The study would not commence until after the Giotto launch, and even if favaourably assessed would not come up for selection until the end of 1987 at the earliest. [May's *JBIS* contains a detailed paper on the proposed Giotto II mission -Ed.]

Outside of the cornerstone concepts, but still within the planetary mission, the Cassini (Saturn orbiter and Titan probe) joint assessment studies are going well.

An ESA workshop on a Cosmic X-Ray Spectroscopy Mission will be held at Lyngby, Denmark on 24-26 June 1985 as part of the momentum towards realising this particular cornerstone.

SOLAR MAX AND THE CLIMATE

By Richard S. Lewis

The repair of the Solar Max satellite by Shuttle astronauts is allowing scientists to continue their valuable observations of the Sun. The author, who has covered the space scene for many years, describes the importance of this work and what it could mean for the long-term future of the Earth.

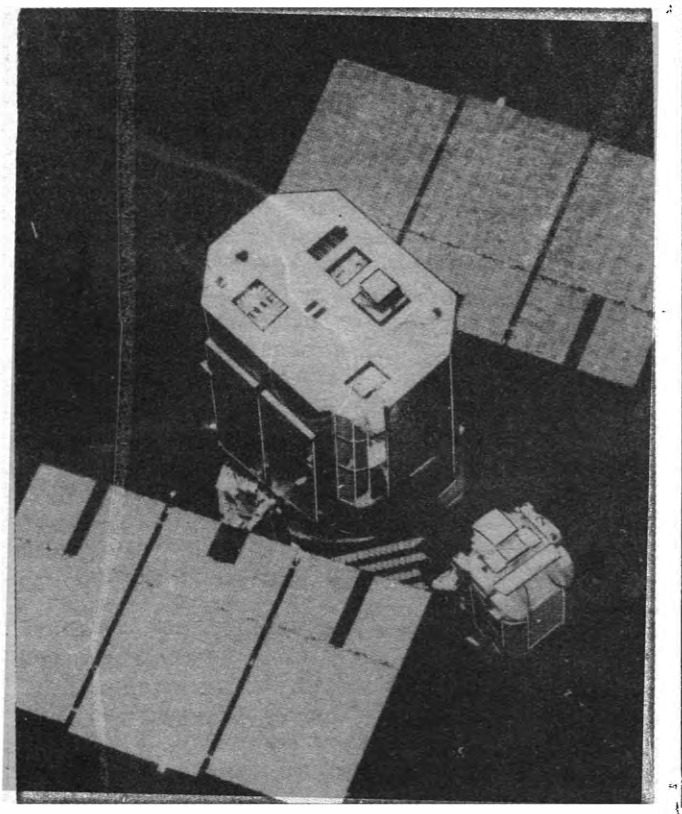
Introduction

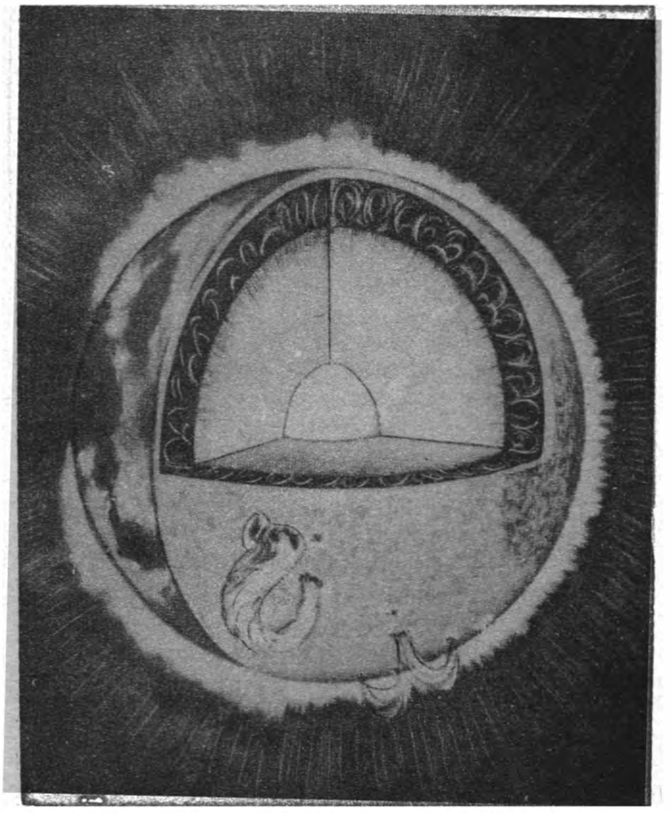
The repair of the Solar Maximum Mission satellite by the crew of *Challenger* on mission 41C in April 1984 was more than just a demonstration of the Shuttle's capability. It restored the ability of the ailing satellite to make precision observations that might have an important effect on our knowledge of climatology.

These have already shown, for the first time in the history of solar observation, a long term decline in the 'solar constant.' This quantity is the sum of solar radiation at all wavelengths reaching the top of the Earth's atmosphere. One of the seven experiments carried by Solar Max is the 'Active Cavity Radiometer Irradiance Monitor' (ACRIM), designed to measure variations in the solar constant with unprecedented accuracy.

Although the solar constant is deemed to have an energy value of $1373 \pm 20\ W/m^2$ [1], attempts to detect significant variations were unsuccessful or ambiguous until Solar Max was launched into orbit on 14 February 1980. Following three years of continuous observations, data showed a sustained downward trend in total solar irradiance amounting to a net decrease of 0.08% from 1980 to the end of 1983 [2]. This was the first definite detection of any long term trend [3].

Astronaut George Nelson attempts unsuccessfully to dock with the rotating Solar Max. *NASA*





A segmented impression of the Sun and its main features. *NASA/JPL*

If the downward trend continued indefinitely, it would eventually alter the climate of the Earth, according to astronomers at NASA's Goddard Space Flight Center, which manages Solar Max. However, they said that they deemed any such continuation 'very unlikely' [4]. Nevertheless, the probability exists that, if solar energy continues to decline at the observed rate, it would result in the onset of a new glacial epoch in about 150 years.

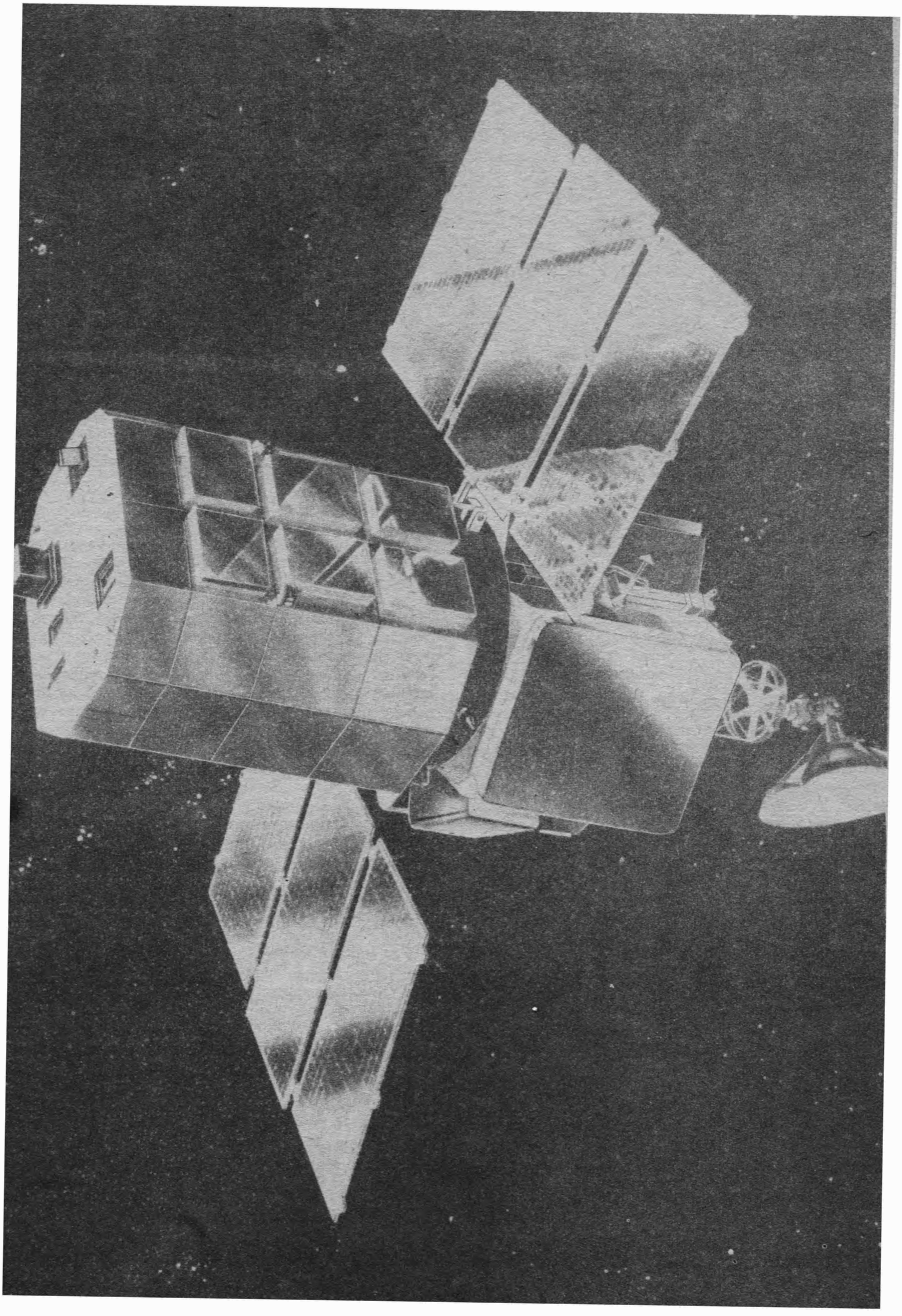
Determining whether the instrument had discovered a new phenomenon or, more likely, picked up a cyclical phase of an old one previously undetected, is the challenge faced by the monitor's science team. The principal investigator, Richard Willson, a solar physicist at the Jet Propulsion Laboratory in California, said that observations must be sustained well into the 1980's, approaching the solar maximum period, to 'determine unambiguously the nature and cause of this apparent long term variation' [5].

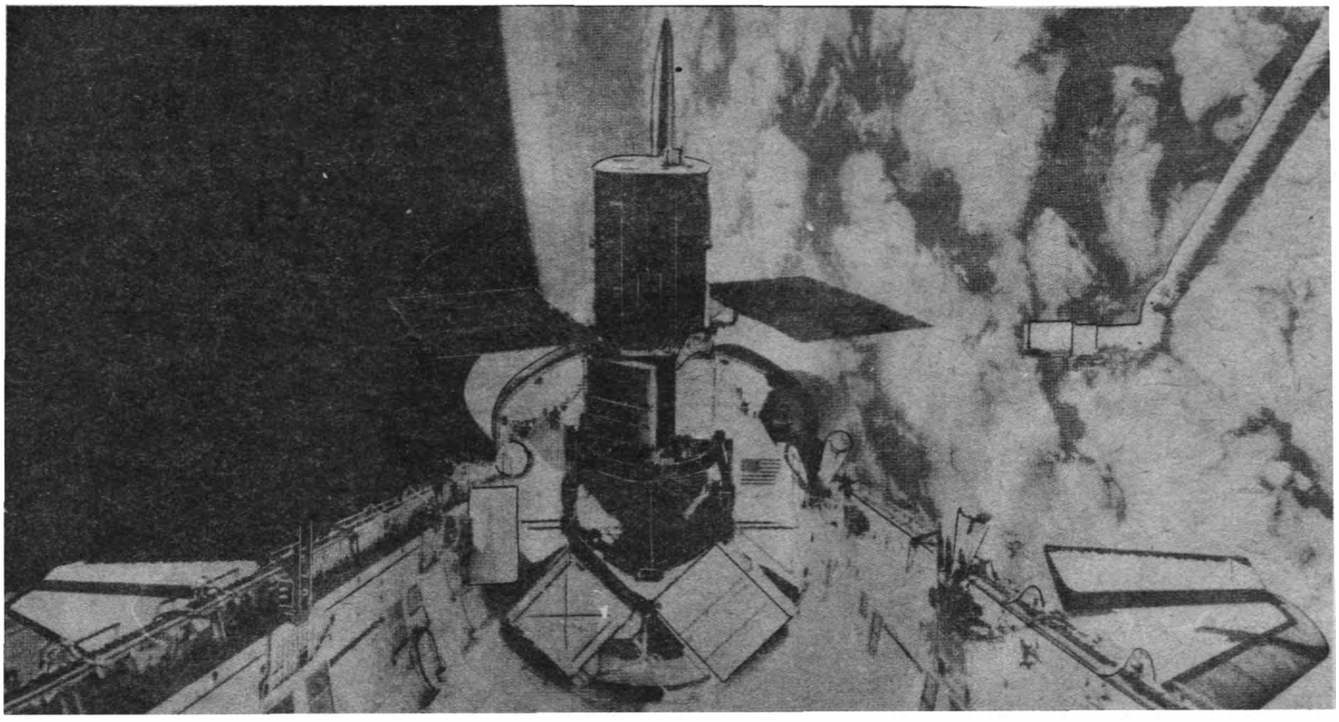
Solar Max Fails

Designed by Willson and his associates at JPL, the monitoring instrument aboard Solar Max is a three-sensor pyrheliometer in which heat produced in a detector by sunlight is compared with heat produced in the same detector by a known amount of electrical current. For 300 days after Solar Max reached orbit, it maintained a measurement precision that reduced uncertainty to less than 0.002%. On 23 November 1980, three fuses failed in the satellite's attitude control system and accurate pointing of the observing instruments was lost.

Goddard's controllers managed to stabilise the satellite by putting it into a slow spin with magnetic torquer bars so that the spin axis pointed toward the Sun but, because the satellite was not designed for spin stabilisation, its axis wobbled. This induced a pointing error of about 10°

Facing page: An artist's impression of Solar Max in orbit. The instruments view through the apertures at left. *NASA*





Solar Max berthed in the Shuttle's cargo bay. *NASA*

and spoiled observations by the Ultraviolet Spectrometer/Polarimeter and X-ray Polychromator.

At about the same time, the main electronics box serving another instrument, the Coronagraph/Polarimeter also failed and shut down that experiment. In June 1981, a fourth instrument, the Hard X-Ray Imaging Spectrometer, was knocked out by a short circuit.

These mishaps left only three of the seven solar experiments functioning: the Gamma Ray Spectrometer, the Hard X-Ray Burst Spectrometer and the solar constant instrument. They were not dependent on fine pointing to gather usable data; nevertheless, the loss of fine attitude control degraded the performance of ACRIM by an order of magnitude, reducing its precision to 0.02% [6]. Nevertheless, it was still better than that of any previous instruments carried on high altitude balloons and aircraft, sounding rockets and the experimental meteorological satellites, Nimbus 6 and 7.

Loss of fine pointing instruments blurred the correlation betv een sunspot activity and variations in the solar constant. Goddard observers noted that the passage of a large sunspot group across the Sun was coincident with a short-term decrease of 0.2% in the solar constant. Where had the missing energy gone? [7].

Willson reported that solar irradiance was modulated by sunspots and faculae (bright areas) in active regions of the Sun; sunspots were correlated with dips of up to 0.25% in the average total irradiance. On the other hand, large faculae appeared to cause an increase in irradiance near active regions with sunspots. 'Temporary decreases in solar irradiance caused by the transit of solar active regions containing sunsport areas across Earth's side of the Sun are the dominant variable phenomenon in ACRIM results,' he said [8].

The further pursuit of these observations rested on the repair of the crippled observatory. Except for brief observations by solar monitors on Spacelab flights, the only hope of maintaing continuity of high precision observations lay with the success of the first satellite repair mission.

Its objectives were to restore Solar Max's fine pointing capability by replacing the attitude control system and to bring the Coronagraph/Polarimeter back into service by replacing its defective main electronics box. This was possible because Solar Max was the first satellite designed to be repaired in this way in orbit, even though it had been built and launched before the Shuttle era. With these changes, it regained the observational precision it had displayed in its first 300 days. Only the short-circuited Hard X-Ray Imaging Spectrometer was not repairable. In the light of the discovery of long term variability of the solar constant, the scientific importance of the repair mission can hardly be overstated - it ranks with the orbital repair of the Skylab space station in 1973.

Solar Max data might add a new parameter to the current theories of climate variation, none of which take into account variations in the solar constant. Although long suspected, these variations were beyond the pale of acceptable theory because they could not be discerned until now.

The Solar Constant Problem

The term itself was invented by a French physicist, Claude Pouillet, who is credited with measuring the intensity of sunlight for the first time in 1837. He found that the Sun's rays illuminating a square centimetre of the Earth's surface raised the temperature of 1.7633 g of water by 1 °C per minute. This value he identified as a constant in nature.

In the United States, efforts to monitor the solar constant from mountaintop observatories were carried out from 1902 to 1962 by the Smithsonian Institution. High altitude balloon experiments and measurements from aircraft were conducted by the United States and the Soviet Union. There were hundreds of observations but, because of atmospheric interference, they were of low precision and none found any clear evidence of variation over time.

In the late 1960's, NASA flew pyrheliometers on Convair 990 aircraft with an uncertainty of 1%, much too high to make a determination of variance. Two active cavity radiometers were sent aloft in high altitude balloons by JPL in 1968 but a quartz window through which the Sun had to be observed degraded the results. The first

pyrheliometer measurements of the solar constant in space were made on the Mariner 6 and 7 spacecraft *en route* to Mars in 1969 but performance flaws resulted in uncertainties of 1-2%. In 1975, Earth Radiation Budget experiments that involved measurements of the constant were carried on Nimbus 6 and 7 but, again, solar irradiance sensors exhibited an uncertainty of 1% in results [9].

The question of whether the solar constant was really constant or not was unanswered after 143 years of effort until Solar Max found the first evidence. The downward trend that Willson and his colleagues found in three years of data 'may be the beginning of secular variation in solar luminosity on a solar cycle time scale,' Willson said [10]. He added, 'Whether or not there is climatological significance in the results will not be apparent until many more years of continuous data are acquired, but the discovery of variability on solar active region time scales has provided substantial new insight into the physics of solar activity in the early years of the Solar Max mission. The timescale of variability ranges from seconds to the duration of the record.'

Speculating on the trend, a JPL news release noted that a cumulative decline of only 0.5% a century would have climatic impact and a drop of 1% would lower global temperature by 1°C. If total solar irradiance decreased by 6%, the release added, the entire Earth would be covered by ice [11]. If the rate of decline observed by Solar Max continued indefinitely, total solar irradiance reaching the Earth would drop 2% in a century.

A more conservative scenario of such a doomsday was offered in 1958 by Ernst Opik at the University of Maryland. He said that a 13% decline in solar irradiance would result in a global ice cover a mile thick [12].

These speculations underscore the view of many meteorologists that determining the extent of variability of solar irradiance is fundamental to understanding and predicting climate change. 'The obvious question,' said the German meteorologist, Herman Flohn, 'is to what extent the amount of insolation [total solar irradiance] is really constant' [13].

Two climatologists, M.I. Budyko and W.D. Sellers, concluded that a relatively small decrease in incoming solar radiation is sufficient for the development of an extensive ice sheet [14]. Two other investigators, R.T. Wetherald and Syukuro Manabe, found that Earth's water cycle is highly sensitive to small changes in the solar constant. They said that a 6% rise in solar irradiance would produce a 27% rise in the hydrologic cycle, bringing higher rainfall especially to the middle latitudes. Wetherald and Manabe commented that it was 'desirable to know how climate responds to changes in the solar constant before investigating the mechanisms of climate change' [15].

A number of theories have been propounded to account for the cycle of glacial and interglacial episodes that have characterised the Quaternary, the present period of geologic time. At least four major ice ages separated by shorter intervals of warm climate (interglacials) have been identified in the geologic record of the last 1.5 million years. Analyses of sea bottom cores indicate that there may have been twice that number.

Whether the glacial -interglacial cycle ended with the end of the Wisconsi-Wurm ice age just 12,000 years ago is a question that affects the future of civilisation. In this context, the identification of long term variations in the solar constant and their climatic effects is a crucial scientific issue. That becomes apparent when it is realised that the main centres of population, industry and agriculture of western civilisation were inundated by ice or were polar deserts during the last ice age.

Although evidence of the glacial-interglacial cycle and its periodicity has been found in polar ice sheets, moraines, sea bottom cores and Alpine valleys, the *cause* of the cycle can only be inferred from these findings. The predominant inference is the 'Astronomical Theory,' which was developed in its current form early in this century by two mathematicians, Ludwig Pilgrim, a German, and Milutin Milankovitch, a Yugoslav. It attributes climate change to variations in the obliquity (tilt) and precession (wobble) of the Earth's axis and in the eccentricity of its orbit, which alter the intensity of sunlight falling on various parts of the Earth. Decades of research and computation have found some correlation between the frequencies of these variables and the glacial-interglacial cycle.

The logical conclusion of the Astronomical Theory is that unless Man intervenes in the natural process by creating a massive 'Greenhouse effect' with the burning of fossil fuels and deforestation, another ice age is inevitable. However, the theory does not say when.

Other theories advance other causes of climate variation: persistent and widespread volcanism, filling the atmosphere with dust and aerosols to block out sunlight; tectonic activity rearranging the land masses and the oceans; or clouds of cosmic dust through which the Earth passes from time to time.

What is missing in all this speculation is the most basic parameter of all: variations in the solar constant.

The Solar Max repair mission, so well described in the September/October 1984 issue of *Spaceflight* by John Pfannerstill, makes it possible for the scientific teams with instruments aboard the satellite to pursue one of the remarkable discoveries of the Space Age. Willson has said that the restoration of Solar Max's fine pointing capability should enable ACRIM to continue precise observations until at least 1988. Beginning this year, the Shuttle will fly annual Earth Observation missions using the active cavity radiometer flown on Spacelab 1 to verify Solar Max data. At the end of this decade, a successor to ACRIM is to be carried aboard NASA's large Upper Atmosphere Research Satellite. Meanwhile, European Space Agency investigators are planning to observe the solar constant with pyrheliometers aboard Spacelab flights during the next five years.

With the products of space technology, the study of climate has at least turned to the Sun.

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HUMAN PROBLEMS OF SPACE TRAVEL

By Sqn. Ldr. Richard Harding*

As space flights become longer in duration, the effects of weightlessness upon humans will become more critical. Resolving the issues is crucial for future space travel. As astronautics pioneer Konstantin Tsiolkovsky said, 'The Earth is the cradle of mankind, but one cannot remain in the cradle forever.' The author considers some of the problems as presently perceived.

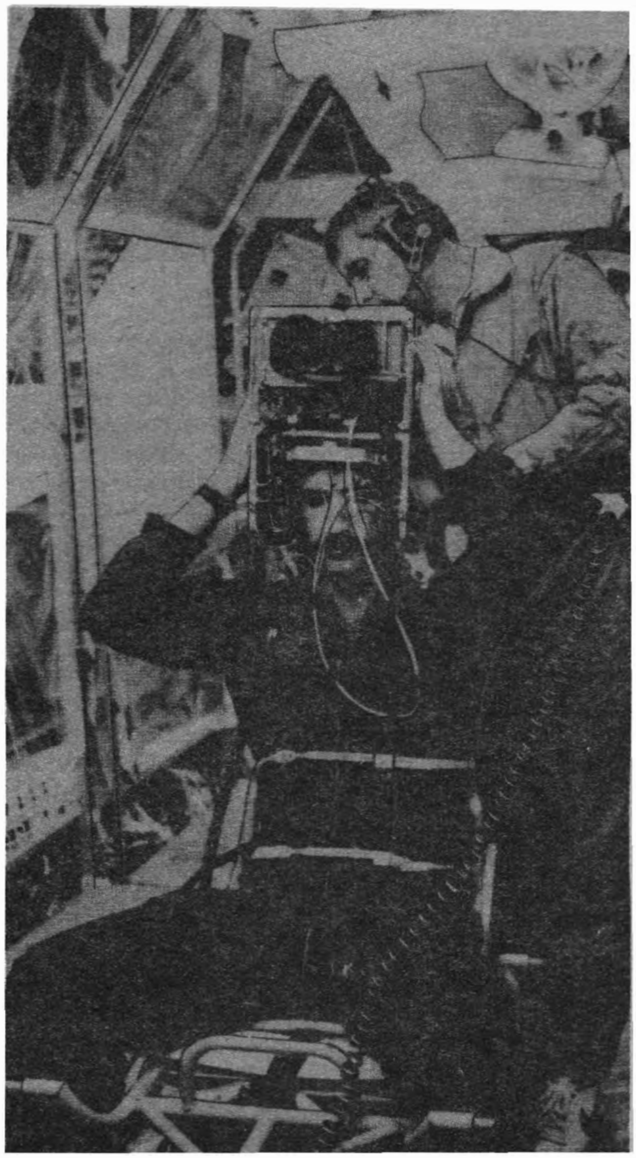
Introduction

In early October last year, just over 23½ years after Yuri Gagarin ventured into space, other Russians successfully concluded the longest continuous period by men in space to date, 237 days, so taking the total achieved by the USSR and US space programmes to well over 4000 man-days. Physicians and physiologists have played a vital role in the success of the manned programmes, at first by ensuring survival itself (for example, in terms of protection against the high accelerations of launch and re-entry, and in the design and maintenance of spacecraft environments to ensure protection against hypoxia, decompresssion sickness and ebullism) and, more recently, by investigating the effects of relatively prolonged space flight upon human physiology. It is with these long-term responses that we are now most concerned since they will intimately, and ultimately, affect the chances of successful space exploration by human beings.

The Problems

From the earliest flights it was recognised that microgravity, or 'weightlessness,' presented the single greatest threat to the physical adaptability of man in space: the body does not like departures from the normal (1g) gravitational field of Earth. Effects on four main areas of physiology have been well-documented by Soviet and American space scientists, although it must be remembered that the findings are from a small and highly selected subject group for whom the operational requirements of the mission were paramount; the wishes and needs of Earth-bound investigators being subservient.

The neuro-vestibular system (the organs concerned with vision, balance and co-ordination) the cardiovascular and homeostatic (body fluids) systems and the musculoskeletal system are all profoundly affected by microgravity. The Skylab and Salyut missions confirmed the findings of shorter duration flights and have revealed the timescales of the development of some of these changes and of the adaptability, if any, to them. Thus, the most obvious effect of microgravity on the neuro-vestibular system is the development of space motion sickness, the susceptibility to which is impossible to predict before flight and which seems to affect most space travellers to some degree. It develops within hours of take-off and can (and has) seriously compromised the success of some missions. Fortunately, it can be suppresed by drugs if



Spacelab 1 payload specialist trains with the device for the 'Effects of Rectilinear Accelerations, Optokinetic and Caloric Stimulations in Space' experiment. Eye movements were recorded as the subject was moved around. *NASA*

necessary and usually resolves anyway within three to six days, as the body's vestibular system adapts to what has been called its 'zero-g set point.

On the other hand, cardiovascular and homeostatic changes, in the form of alterations in heart rate, blood pressure and blood flow, of marked fluid shifts from the lower limbs to the core and upper body (causing feelings of facial fullness and stuffiness) and of unexplained falls in red blood cell mass, do not quickly resolve in space, taking 1½ months to reach their zero-g set points and with further changes thereafter. The consistent loss of calcium and nitrogen in the urine of space travellers, with consequent demineralisation of bone and muscle atrophy, begins shortly after take-off, as the muscular effort needed for physical work and the control of posture is reduced, and, in the case of bone loss, does not appear ever to reach a set point of adaptation. Indeed, it has been predicted that irreversible changes in bone structure and metabolism will be manifest after about 8-10 months in space if no protective measures are adopted. This phenomenon, combined with others such as the orthostatic intolerance of the cardiovascular system (the inability of the body to tolerate an upright posture), which frequently manifest on return to Earth as a tendency to

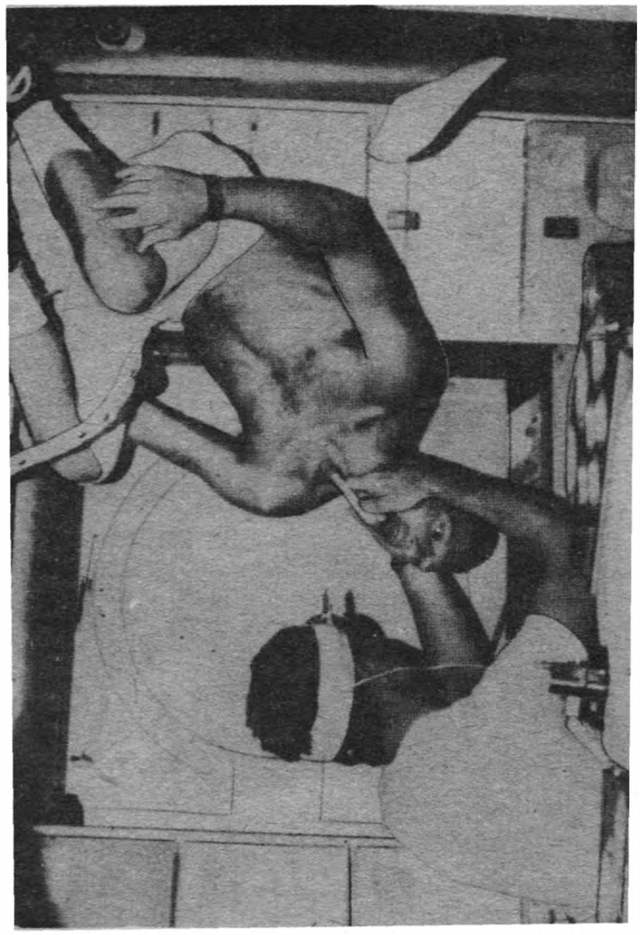
* *Dr. Harding is the Deputy Head of the Altitude and Breathing Systems Research Section of the RAF Institute of Aviation Medicine in Farnborough. The paper was originally presented at the Society's Space '84 conference in Brighton under the title of 'Human Physical and Mental Adaptability.'*

faint is a demonstration of another vitally important physiological aspect of prolonged space journeys: that of the need to re-adapt on re-exposure to 1g. It is quite clear, therefore, that these physiological disturbances, even if tolerable in microgravity, could actually limit Man's ability to undertake long journeys into space by virtue of his *in*ability to recover on return. The loss of bone substance and the cardiovascular intolerance are not greatly modified by extensive exercise or other preventative regimes (e.g. thigh cuffs, anti-g suits and saline ingestion), and the present conclusion must be that some form of local (e.g. small on-boad centrifuges) or general (e.g. rotation of the whole craft) artificial gravity will be essential for long duration space missions.

Furthermore, there may well be other, as yet undefined, effects on human physiology; such as, for example, the response of the body to the gradual but sustained rise in radiation exposure levels observed throughout space missions already undertaken. For the US Space Station, it has been estimated that a crew member will receive 15 rads per 90 day tour, which is higher than any acceptable exposure for Earth-bound employment; but no large impact of this will be seen until ten such tours have been completed (i.e. 150 rads received). This total dose may be expected to increase the risk of developing cancers and to reduce life expectancy by 150 days. (This figure should be seen in perspective, however, since the length of a coalminer's life may be expected to be reduced, by virtue of the risks associated with that job, by 1100 days, while that of a teacher is reduced by 30 days).

The least studied areas of human adaptability to space are psycho-physiological, or behavioural, aspects; yet these are potentially at least as important. If the problems of physical adaptability can be overcome, mental adaptability to the behavioural stresses of space flight may well come to dominate Man's ability to travel further into space. Many such behavioural aspects can be identified but very few have so far received attention from the

Early US space missions did not suffer from space sickness, possibly because the capsules were so cramped. This is Gordon Cooper aboard his Mercury craft in 1963. NASA



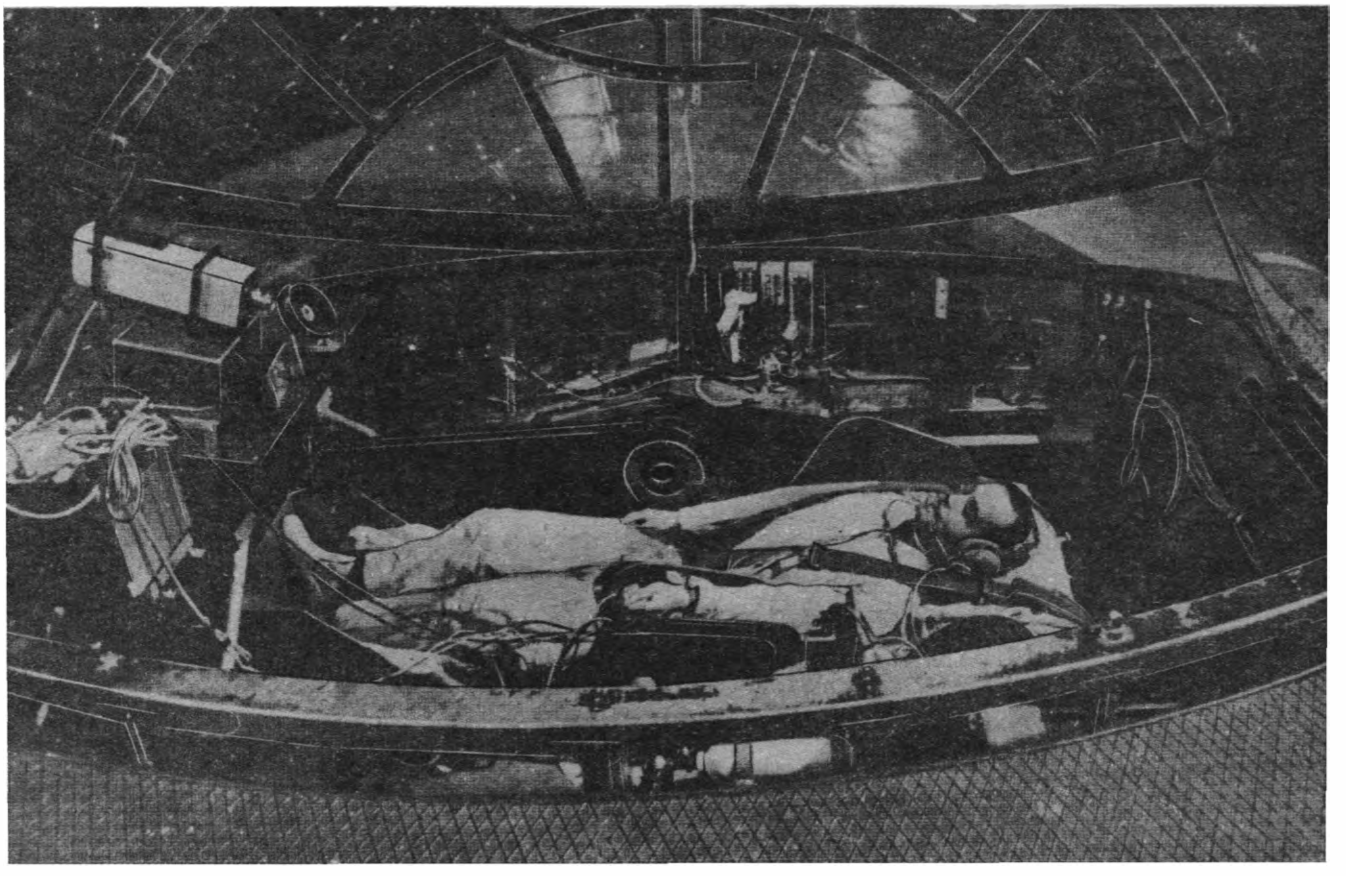
Skylab allowed the Americans to conduct lengthy medical experiments in space for the first time. NASA

programme scientists. This is understandable, given the operational constraints referred to, but disappointing since 'behavioural correlates' would undoubtedly add meaning to the mass of 'pure' physiological data being gathered at present. As mission lengths increase and the exploration by Man of remote planets and galaxies is considered, these aspects will have to be addressed.

The process has already begun, with astronaut/crew selection now widened to supplement the 'super-hero' astronauts of previous years with relatively ordinary payload specialists - scientists whose job it is to accomplish defined tasks in space once delivered there by the pilots and mission specialists. Thus, while the psychological and psychiatric criteria for the latter have been well-defined and tested, and include such predictable features as general emotional stability, high motivation for flying and positive attitudes towards self, the same criteria may not be as relevant for payload specialists.

The problems of isolation and confinement, already graphically described in studies of Earth-bound populations, particularly for example in Antarctica and submarines, include sleep disturbances, anorexia, boredom and depression, restlessness, disorientation and deterioration in mental and physical performance. Such problems, due to isolation/confinement, have not proved troublesome in space so far, but those due to hyperarousal or sensory overload have. In fact, very similar clinical features are seen in these cases with insomnia, depersonalisation and an overall decline in performance having been reported consistently. Indeed, bizarre behaviour attributed to hyperarousal has been responsible for several in-flight incidents and the curtailment of at least one mission.

Group interactions will also become increasingly relevant as not only are more and more personnel required in



Frenchman Patrick Baudry prepares for a run in a centrifuge. Baudry trained as backup on the Soviet-French Salyut mission and will fly aboard the Shuttle in early spring. *CNES*

space at any one time to accomplish large and complicated tasks (as on a space station) but also as very long journeys are planned, or colonies in deep space are established, involving relatively large crew complements. The addition of women to space crews adds yet another dimension to this aspect, for there is no reason to suppose that crews of mixed sex will be any less susceptible to problems of interaction than are similar groups working together in an Earth-bound environment. Careful selection and training, perhaps of married couples, will once again be of value in this area, and it may well be necessary to undertake counselling in group dynamics and behaviour before embarkation of mixed, and indeed single, sex crews.

Having successfully determined the preliminary requirements of personnel for prolonged space adventures, whether in near-space or space stations, or in deep-space on exploratory missions, it will become essential to continue research into aspects of man-machine interaction. Much work has already been carried out into these areas, which may be better termed problems of spacecraft habitability. At least nine such problem areas can be identified and include environmental control (i.e. the control of atmospheric composition, including contaminants, temperature and humidity, and the special needs of extravehicular activities), ergonomic design and space utilisation (i.e. the best use of available space), mobility, exercise and entertainment, together with the more basic essentials of clothing (utilitarian but comfortable), food and drink (palatable and nutritious), waste disposal and personal hygiene. The provision of privacy is particularly important with regard to the last two items and extends to the need for arrangements that allow for private communication with Earth-bound relatives and friends. Nor must health care, both medical and dental, be forgotten, including the need for medical training of crew members and provision of suitable equipment and drugs. Clearly, adequate consideration of all of these factors must be given to ensure as comfortable an existence as possible for the men and women who live and work in space. It will then be essential to monitor the responses of individuals both to their immediate surroundings and to their very presence in space. As such, this process will be an extension of the study of human responses to the overall stress of space flight. At present, such research has been limited to fairly simple monitoring of cardio-respiratory and endocrine responses to stress and has concerned itself with relatively acute changes with very little behavioural correlation.

Finally, to this rather long list of psycho-physiological problems must be added the influence of altered circadian rhythms. The lack of normal external synchronisers of internal body clocks in space, so-called zeitgebers or time-givers such as night and day, has not, so far, proved a problem in space, provided that regular work, rest and feeding patterns are established and adhered to, even if the patterns do not reflect typical Earthly cycles. It is not yet known, however, for how long this so-far relatively short-term adaptation can be sustained, or what adverse effects may develop from it in the long-term.

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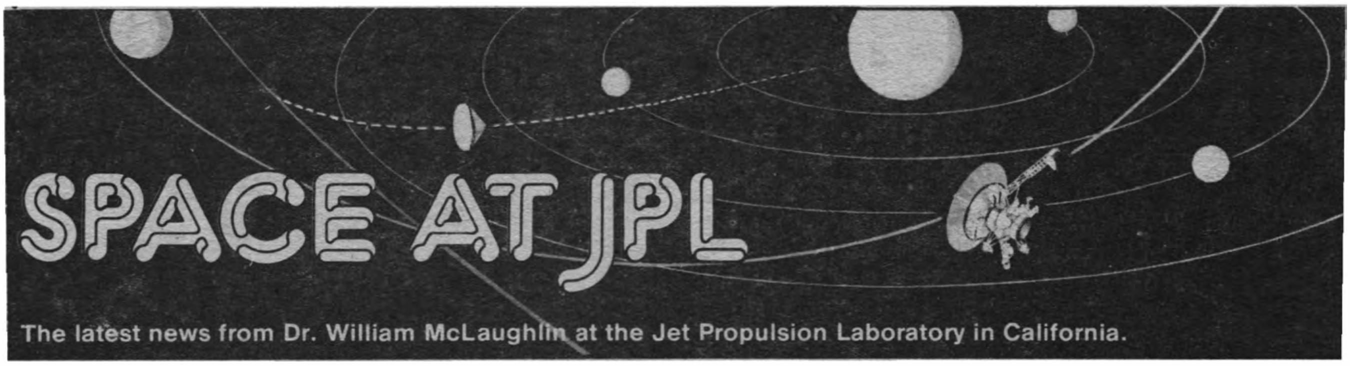


A PECULIAR RING ABOUT NEPTUNE

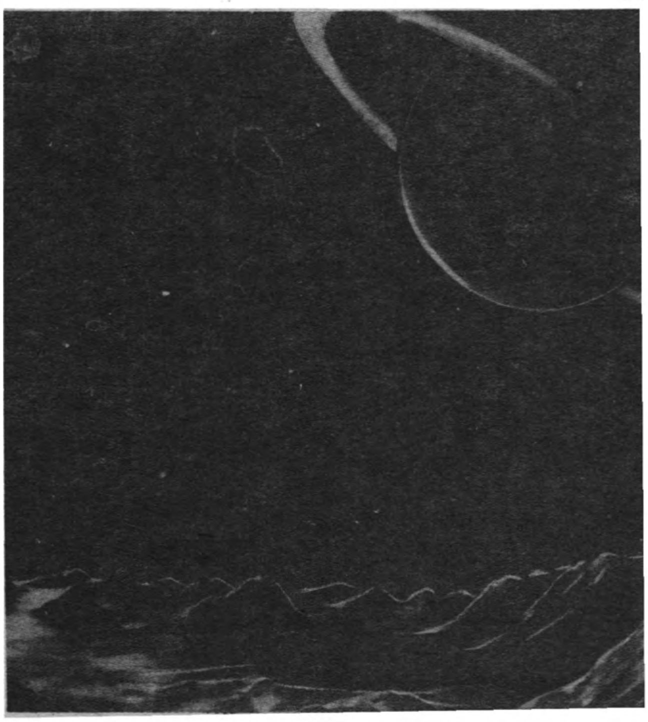
In 1610 Galileo first observed the rings of Saturn with the newly-invented telescope; in 1977 the rings of Uranus were detected by observation of a stellar occultation; and Voyager 1 discovered the Jovian ring during its 1979 flight through that system. Now evidence is accumulating, from analysis of stellar occultations, that the fourth gas giant, Neptune, also has a ring.

The fact of the discovery is not surprising - see, for example, your correspondent's prediction in the August 1980 *JBIS,* p.292. However, the picture of the ring that is emerging is indeed strange. In some places it seems to be about 10 km wide, while in others it spans several hundred kilometres. The ring may be discontinuous since, at times, it has not manifested itself as expected during the course of an occultation track.

The unusual morphology of the ring might be related to Neptune's typical satellites: Triton is in a retrograde orbit and that of Nereid is highly eccentric.

Attempts to image the ring using powerful charge-coupled devices with a telescope have not been successful to date. Possibly the ring is very dark, as are the Uranian rings. In any case, a detailed analysis of the structure will have to wait for the Voyager 2 flyby of Neptune in August 1989.

An artist's impression of a ring about Neptune, as perceived from Triton, prior to the rescent discovery. *NASA/JPL*



ASTEROID OPTION FOR GALILEO

The NASA Administrator James Beggs, has agreed to add an asteroid option to the Galileo mission and to change the arrival date at Jupiter from 29 August 1988 to 10 December 1988. The option will permit a later decision to fly by the asteroid Amphitrite in December 1986.

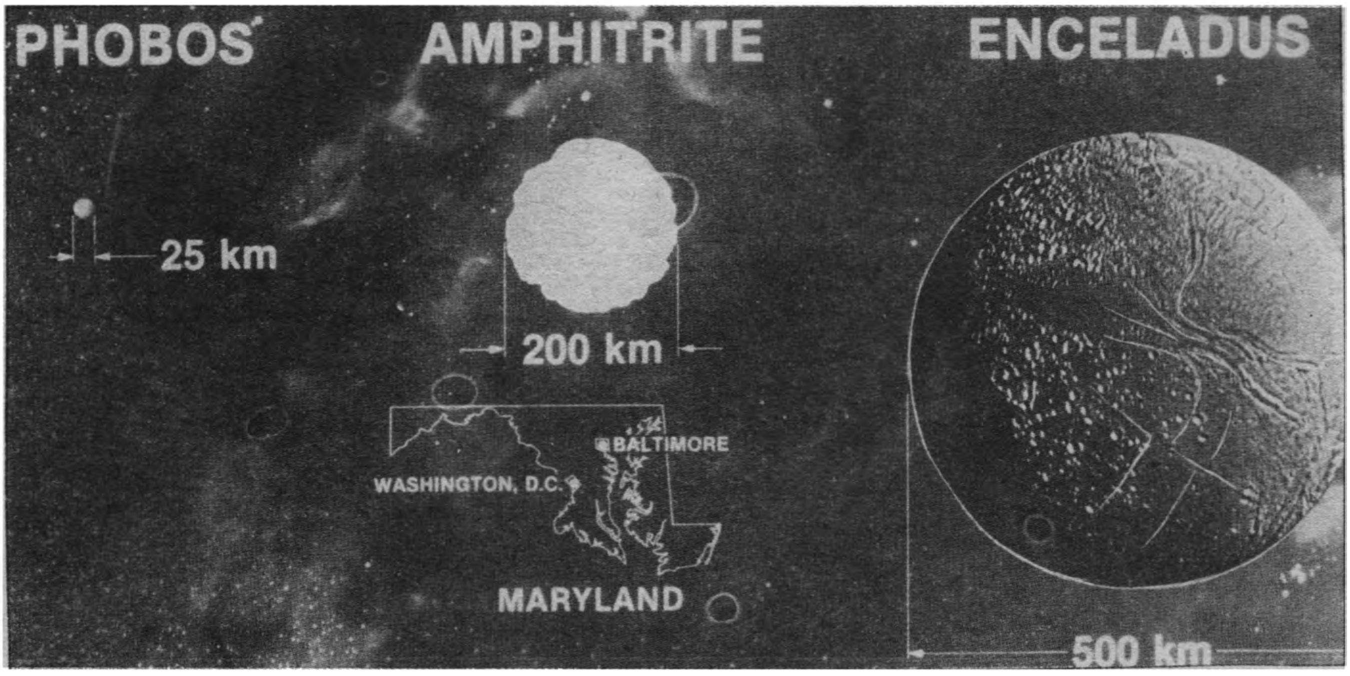
The decision on whether or not to exercise the flyby option will be made about two months after Gelileo's May 1986 launch. It will be based upon an assessment of the health of the spacecraft and the mission operations system. The flyby will be treated as an add-on, not a primary mission objective, and will not be permitted to compromise the basic mission objectives or to add any risk to the Jupiter mission, constrained by the launch vehicle energy and existing launch window, has been developed.

If the asteroid option is exercised it would represent a second major serendipitous 'first' for NASA in the domain of small-body exploration; the International Cometary Explorer (ICE) has been diverted from near-Earth space to conduct the first exploration of a comet, in September of this year (see 'Through the Tail of a Comet' in the November 1984 issue).

Amphitrite is a large, main belt asteroid approximately 200 km in diameter. From Earth it appears as the 12th brightest asteroid. Flyby distance from Amphitrite would be determed by spacecraft safety considerations, possibly yielding a range of 10,000 to 20,000 km. At that distance significant scientific data could be obtained. Images would have a resolution of 200 m to 300 m, high-quality infrared spectral mapping would reveal facts about Amphitrite's mineral composition and a good mass determination could be made using measured changes in the trajectory of the spacecraft due to the asteroid.

The effect on the Jupiter mission would be relatively minor. Since the flyby would require added expenditure of propellant in the early mission phase, the number of satellite-tour orbits of Jupiter would be decreased from 11 to 10 (the pre-Amphitrite-option interplanetary and Jovian trajectories for Galileo were discussed in the July/August and September/October 1984 editions of this column). Consequently, the length of the tour of the Jovian system has been extended from 20 months to 22 months to permit the achievement of all the major objectives previously encompassed by the 11-orbit tour.

The asteroid option clearly represents a cost effective way to acquire new information about a major component of the Solar System and it has been unanimously endorsed by the Galileo Project Science Group and the Small Bodies Working Group of NASA's Solar System Exploration Committee. There is no near-term cost impact on the Galileo mission owing to the incorporation of the flyby option.



The asteroid Amphitrite may be observed *en route* by the Galileo spacecraft on its flight to Jupiter. Here it is compared with similar-sized objects. *NASA/JPL*

Eventual added costs, estimated at $20 to $25 million, are attributable to a five-month mission extension arising from the delayed arrival data and the increased tour time.

ELECTRO-OPTICS AND LASERS

In simplest terms, the scientific exploration of space involves the acquisition of data and its transmission back to Earth for analysis. Data can be divided into two types: those acquired by remote sensing (such as through imaging) and those obtained by *in situ* measurements (such as for fields and particles phenomena). There is a similar classification of methods of data transmission. The information can be returned *via* electromagnetic carrier, radio is a popular mode, or actual samples can be brought back to Earth (Apollo Moon rocks provide the most notable example of this method).

The subject for this month's review of an advanced concept cuts across data acquisitions and transmission and looks at some of the ways that optical frequencies can be employed in these two areas.

Passive remote sensing at optical frequencies has provided some of the most spectacular returns from space missions, with detailed pictures of the Moon and planets. In 1983 the Infrared Astronomical Satellite (IRAS) extended our spectral coverage of the Universe to the infrared and the ATMOS experiment onboard the Shuttle (see the June 1984 edition of this column) provides high spectral resolution of the Earth's atmosphere.

A remote-sensing instrument with considerable promise is the imaging spectrometer and for the past several years NASA has sponsored development of this instrument for Earth applications. With this instrument imaging is accomplished in many contiguous, narrow spectral bands. For example, a Shuttle Imaging Spectrometer Experiment (SISEX) proposal originating at JPL would cover the visible and near-infrared spectral range from 0.4 to 2.5 microns (a micron is a millionth of a metre; visible light extends from about 0.4 to 0.7 microns). The spectral bands over this range would be only 10 to 20 nanometers in width (a nanometer is one thousandth of a micron). An imaging spectrometer has been flown by NASA onboard a C-130 aircraft and another instrument is being constructed for flights in a NASA U-2 aircraft, starting in 1986. It has been demonstrated already that an imaging spectrometer can be used to identify certain minerals and the capability has obvious application to orbiters about other planets. In fact, the Mars Observer Project at JPL (formerly called the 'Mars Geoscience/Climatology Orbiter'; see the December 1983 and May 1984 editions) has an imaging spectrometer listed in its preliminary payload manifest. Final payload selection will occur in February 1986.

Remote sensing at optical frequencies can also be accomplished by active devices such as lasers (an example of active remote sensing at other than optical frequencies is the imaging radar system flown on two Shuttle flights and on Seasat in 1978). Lasers can be used to investigate the composition of the atmosphere, to measure meteorological parameters such as wind speed and to study crustal dynamics.

An example of atmospheric composition studies is the Laser Absorption Spectrometer (LAS), which was the first active laser used in this type of remote sensing from an airborne platform. Using this device, ozone and water vapour measurements have been made. Studies have shown that lasers onboard the Shuttle or a satellite can also be used to measure winds in the troposphere to an accuracy of 1 m/s. Finally, crustal dynamics can be investigated by bouncing very short laser pulses from space off ground ground-based retroreflectors. A precision of 1 to 2 cm for the distance between the retroreflectors can be achieved.

Space communications by means of lasers offers the lure of high data rates. Lasers allow the beam of energy, carrying the data, to be tightly focused. The 3.7 m high-gain antenna on the Voyager spacecraft spread its radiofrequency power over an area equal to one million times the cross-sectional area of Earth while transmitting during an encounter with Saturn. An optical device with an aperture of only 10 cm would spread its power over only one Earth cross-sectional area from the same range.

Studies have shown that this concentration would result in data rates from three to ten times higher for lasers than for radiofrequency systems at Saturnian range.

The highest Voyager data rate at Saturn was 44.8 kilobits per second at X-band. Another study has shown that 4 megabits per second could be transmitted from Venus to Earth; the 1988 Venus Radar Mapper (VRM) will have a maximum data rate of 268.8 kilobits per second *via* a classical radio system.

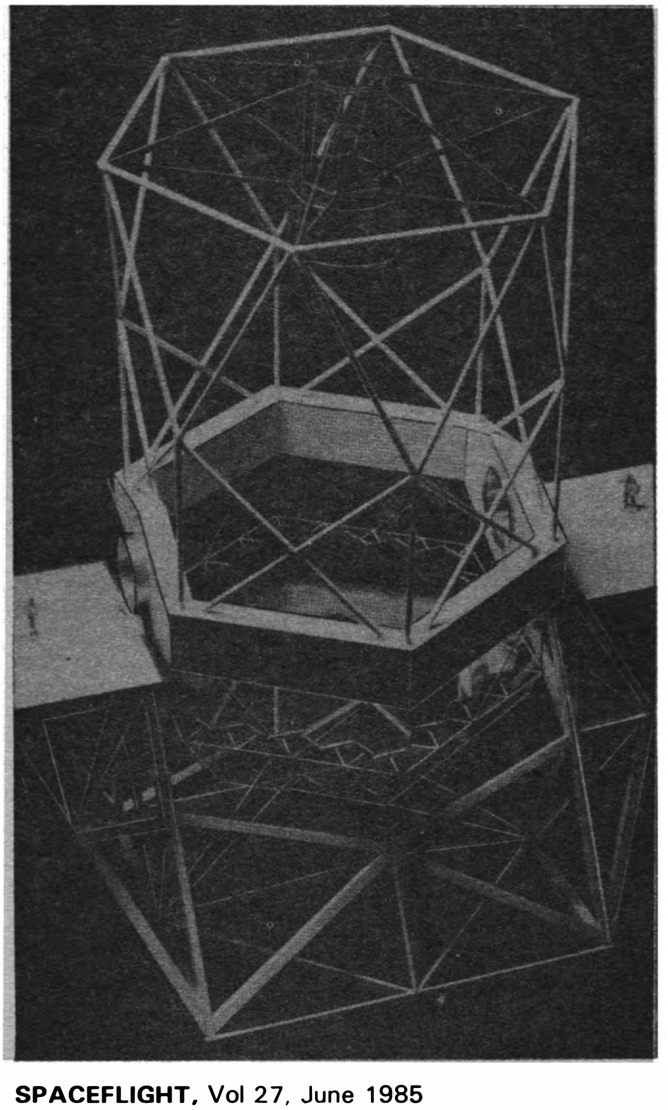
Thanks are due to Dr. E. David Hinkley of JPL for information on the subject. More detailed information is available in papers by Hinkley and his colleagues in the October 1984 and February 1985 issues of *Laser Focus/Electro-Optics.*

KECK TEN-METRE TELESCOPE

The W.M. Keck Foundation of Los Angeles has proposed to grant $70 million to the California Institute of Technology (Caltech), Pasadena, for construction of the world's largest optical telescope. The grant will be made upon satisfaction of certain contractual conditions. This is the largest private gift ever made for a scientific project and replaces an earlier $36 million grant (by the Marion O. Hoffman Trust) to the University of California at Berkeley for construction of a 10 m telescope.

The Keck Telescope will be based upon a segmented-mirror technology that has been developed at the University of California since 1977 by Dr. Jerry Nelson and his associates, as described in the April 1984 edition of this column. Caltech (which operates JPL for NASA) and the University of California will jointly build and operate the telescope. The total cost of the instrument will be approximately $85 million when it goes into operation in 1992. Ground breaking at the observatory site on Mauna Kea in Hawaii will take place early next year.

The 10 m Keck telescope will be built by Caltech and the University of California, to be placed atop Mauna Kea, Hawaii for the start of observing in 1992. The Palomar telescope has a 5 m main mirror.



The segmented main mirror of the telescope will be built up from 36 separate, adjoining mirrors, each 1.8 m across and only 7.5 cm thick. This composite structure will actually be lighter than the mirror of Caltech's 5 m telescope at Palomar and the entire Keck Telescope, at 158 US tons, will be less than one third the weight of the 5 m telescope. Each of the 36 individual mirrors will be precisely positioned up to 300 times per second by a computer-controlled system in order to achieve maximum efficiency of photon collection and transport.

Clearly, we are pleasurably immersed in an era of telescope building. In 1986 NASA's 2.5 m Hubble Space Telescope will be launched into Earth orbit to achieve high-resolution images above the smearing influence of the atmosphere. Several very large Earth-based telescopes are in the planning stages by the United States, the European Southern Observatory group (eight nations), the Soviet Union and Japan.

ACRONYMESE

One list of acronyms employed by the Voyager project contains approximately 1400 entries. The actual number of acronyms in fairly frequent use by project personnel probably exceeds that amount. Similar scores are chalked up by other projects and organisations.

The obvious intent of using an acronym is to save time and effort. Technical acronyms do not appear to be a new discovery but rather a response to a new environment, where relatively short-lived phrases are used repetitively and economy of expression is clearly advantageous. Thus, instead of laboriously referring to the 'Telecommunications Prediction and Analysis Program' a hundred times during a talk, one just substitutes 'TPAP' (computer programs are invariably named with acronyms).

In addition to computer programs, acronyms are applied to projects (VRM: Venus Radar Mapper), spacecraft subsystems (DSS: data storage subsystem), people (CMO: chief of mission operations), organisations (BIS), processes (ASCAL: antenna subsystem calibration), natural objects (quasar: quasi-stellar radio source) and many more categories.

Some acronyms have passed directly into common usage, such as NASA and radar, and live comfortably with more conventional words. Usually, however, in polite literary society, away from the technical arena, the relationship is somewhat strained and the use of acronyms can draw critical wrath.

Acronyms can be modified in a limited number of ways with traditional grammatical devices: "JPLer" or "NASA's." Despite this combinatorial flexibility we are probably not threatened by the emergence of acronymese as an independent language owing to its lack of verbs.

OSOH (or so one hopes).

BACK ISSUES

The Society has available some bound and unbound complete *JBIS* volumes for sale. For a list of those available, and their prices, please send a stamped addressed envelope to The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

SHUTTLE 51A MISSION REPORT

By John Pfannerstill

The rescue of the wayward Westar and Palapa satellites last November once again demonstrated the remarkable capabilities of the Space Shuttle. Lost the previous February, the valuable communications satellites were returned to Earth for refurbishment and eventual relaunch to begin their delayed missions.

Introduction

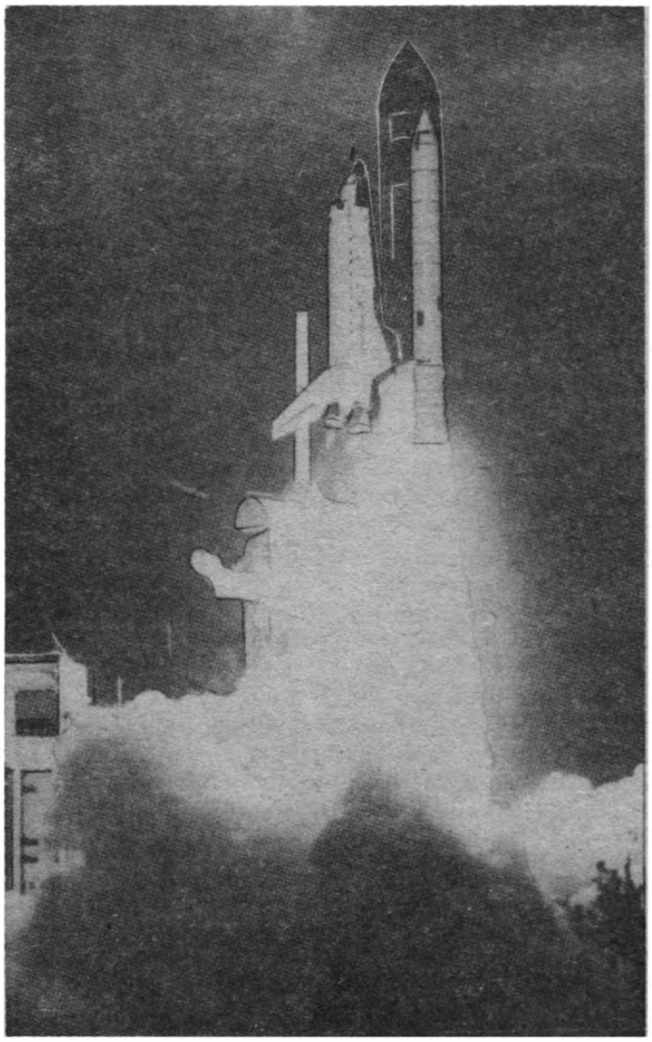
NASA suffered a major blow in early February 1984 when two communications satellites were sent into useless orbits following launch from the Shuttle. The five-man crew of Mission 41B did its job perfectly, releasing both the Westar 6 and Palapa B2 craft from *Challenger* on time and on target. The problems came when the automatic command was sent to ignite the Payload Assist Module (PAM) perigee kick stages attached to each satellite. Incredibly, both PAMs failed after only partial burns, leaving Westar and Palapa in useless orbits far below the desired high-apogee geosynchronous transfer orbits.

NASA officials quickly saw that the unfortunate situation could be solved by another Shuttle flight and a group at the Johnson Space Center in Houston quietly began drawing up plans for a mission to retrieve the two wayward satellites. NASA obtained authorisation for the venture from the insurance underwriters who now owned Westar and Palapa as a result of having paid $180 million in insurance claims to the satellites' original owners, Western Union and the government of Indonesia. In the summer of 1984, NASA officially scheduled the retrieval operation for Shuttle mission 51A, due to lift off in early November 1984 using Orbiter *Discovery*.

The crew consisted of Navy Captain Frederick Hauck (Cdr), Navy Commander David Walker (Plt), Dr. Joseph Allen (MS-1), Dr. Anna Fisher (MS-2) and Navy Commander Dale Gardner (MS-3). Walker and Fisher were both new to space, while Hauck, Allen and Gardner were veterans of one flight each. All except Allen were members of the 1978 astronaut class; Allen was from the 1967 scientist-astronaut group. Among the mission 'firsts' was the fact that Anna Fisher was the first mother to go into space. She and her astronaut husband William Fisher had become the parents of a baby girl in July 1983.

The crew was faced with a challenging task. Unlike the Solar Max satellite, which was picked up and repaired by 41C, neither Westar or Palapa was designed for retrieval. Being standard Hughes HS-376 craft, they had no grapple fixtures for the robot arm, no handholds for an EVA astronaut and no attachments for berthing in the payload bay - all of these would have to be attached in some way.

First of all, however, the awkward orbits had to be lowered for the Shuttle to reach them. This was taken care of in the weeks before the mission by firing each solid-propellant apogee motors. The orbits were then trimmed using the small hydrazine thrusters, putting them into good position for the Shuttle rendezvous: averaging 359 km high, with Westar about 1100 km ahead of Palapa in the same plane. The satellites were also de-spun from 50 revolutions per minute to a more manageable 1-2 rpm. The plan called for the Shuttle to rendezvous first with Palapa and then two days later with Westar.



Discovery roars skyward to begin the historic satellite pickup mission.

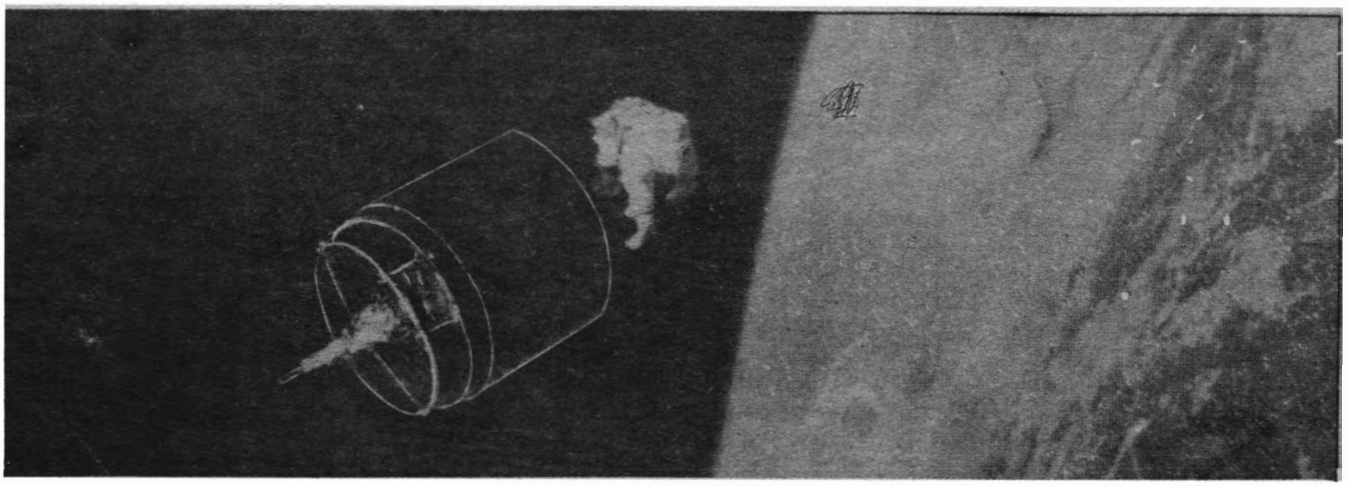
In the case of Palapa, mission specialists Joe Allen and Dale Gardner were to go outside into the payload bay just as pilots Hauck and Walker completed the final phases of the rendezvous. With *Discovery* stationkeeping at a range of about 11 m, Allen was to don a Manned Maneuvering Unit to fly over to the slowly-spinning satellite. Fastened to the front of his suit would be a large device looking somewhat like an inverted umbrella called the Apogee Kick Motor Capture Device or, more commonly, the 'stinger.'

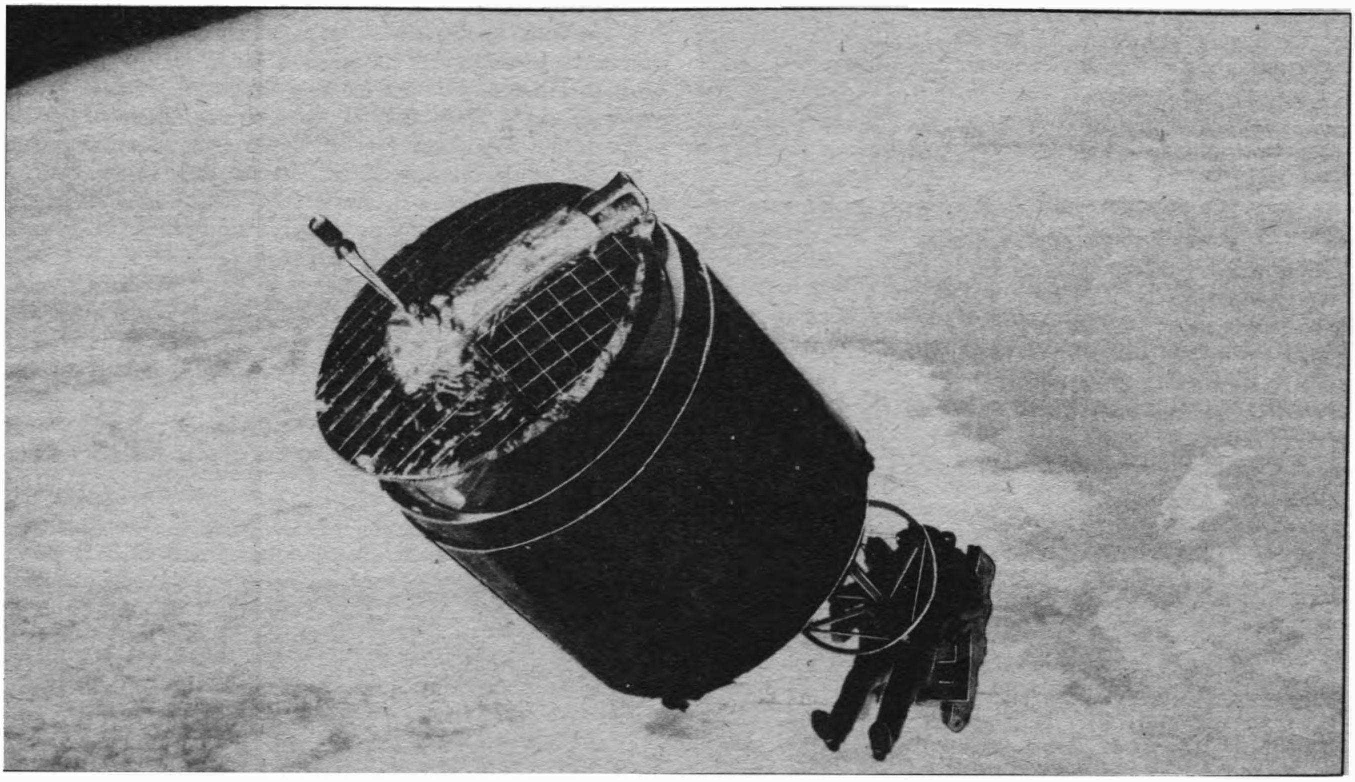
Allen planned to manoeuvre into position at the rear end of Palapa and insert the stinger into the nozzle of the spent apogee motor. Toggle latches at the end of the pole would then be fired, enabling Allen to retract the stinger and achieve a hard dock.

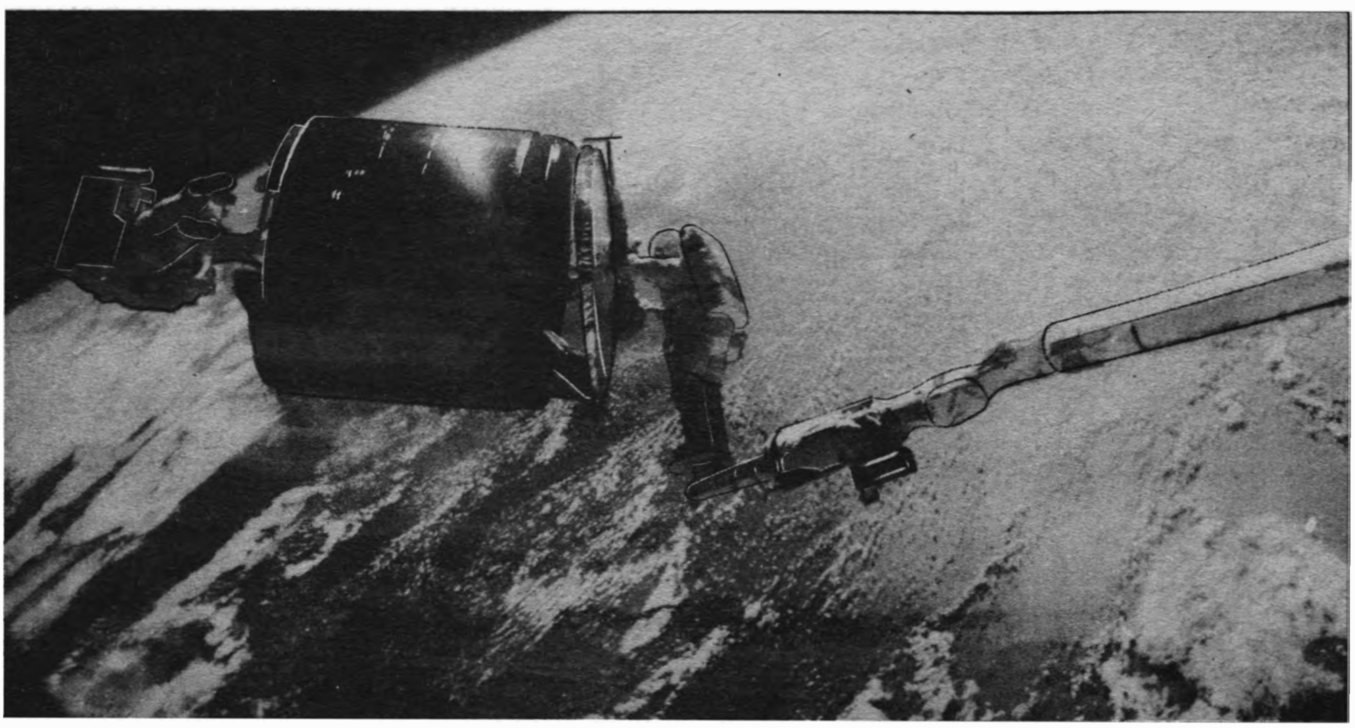
Meanwhile, Hauck would be manoeuvring *Discovery* to within grappling range. As soon as arm operator Anna Fisher indicated she was ready, Allen would fire his manoeuvring unit thrusters to stop the satellite's rotation, allowing Fisher to dock the robot arm to a special grapple fixture on the side of the stinger.

Then, with Allen and Palapa both on the end of the arm, Fisher would turn the satellite upside down so that its 'top' would be facing Gardner, who by this time would have slipped into a pair of foot restraints in the payload bay. Gardner's task was to attach a specially-designed

Facing page: top - Gardner achieves a hard docking with Westar. Centre - Allen with Palapa. Bottom - Allen holds on to Westar.







A-frame structure to the top of Palapa.

Once the A-frame was in place, Fisher would undock the arm from the stinger fixture and re-dock it to another one fixed to the top of the A-frame. This would allow Allen to free himself and park his manoeuvring unit, leaving the base of Palapa clean for the installation of a special payload bay adapter ring.

With Fisher holding the satellite steady with the arm, both astronauts planned to work together to install the massive 250 kg adapter to allow Palapa to be securely latched on to a modified Spacelab pallet. When the installation was complete, Fisher would use the arm to berth the satellite.

With the satellite thus snug in the payload bay, Allen and Gardner's final task would then be to remove the A-frame from the top. This was a vital prerequisite for the return to Earth since the A-frame would sit so high that the payload bay doors could not close. The two astronauts would then come back inside, after an excursion lasting approximately six hours. Two days later, when the Westar rendezvous was planned, the two men would go through exactly the same routine a second time, with the exception that this time they would swap jobs, giving Gardner a chance to fly the manoeuvring unit.

There was no denying that it was an ambitious plan. Even commander Rick Hauck estimated that there was only a 50-50 chance of full success. Partly for this reason, the crew also practised alternate retrieval procedures in the event of unforeseen problems. These backup plans were rehearsed largely at the insistence of Flight Director Larry Bourgeois and, as events later proved, the astronauts were very fortunate that he had been so persistent.

Although the retrieval received most of the publicity, 51A also had two satellites to deploy. It would be carrying the Telesat-H (Anik D2) satellite for Canada and the Syncom 4-1 'frisbee' communications satellite for the US Navy. There was also a commercial scientific payload aboard, the Diffuse Mixing of Organic Solutions experiment, being carried for the 3M Corporation, in addition to the standard Radiation Monitoring Experiment carried on other Shuttle missions.

Mission Day 1: 8 November 1984

The liftoff of *Discovery* took place right on time at 12:15:00 GMT (all times are GMT unless otherwise noted) into partly cloudy skies. Crew seat positions for the ascent had pilots Hauck and Walker in the left and right forward cockpit seats, respectively, with Fisher and Allen behind them in the two mission specialist 'jump seats.' Gardner rode by himself down on the middeck.

The main engine thrust level for the ascent was 104% and the three power plants performed almost perfectly; booster performance was also excellent. Following the boost phase, two Orbital Maneuvering System (OMS) firings put *Discovery* into an initial orbit measuring 298 by 280 km inclined at 28.5°. At the time of the OMS-2 burn, the Orbiter was some 27,336 km behind Palapa but, because its orbit was lower, it was gaining by several hundred kilometres every orbit.

After payload bay door opening, the crew had a rather light day of systems checks and equipment preparation duties. Fisher uncradled and checked out the robot arm and then activated the 3M Corporation experiment down on the middeck.

One of the final tasks of the day was the performance of a 3 m/s OMS burn to close the gap to Palapa further.

The crew of Mission 51A gathers on *Discovery's* flight deck for an on-orbit portrait. From left, they are (bottom row) Anna Fisher and Joe Allen; (top row) Dale Gardner, Rick Hauck and Dave Walker. *NASA*

THE SHUTTLE MMU

The Shuttle Manned Maneuvering Unit has proved to be spectacularly successful in allowing astronauts to move around untethered to their parent craft. The history of the MMU stretches back to Gemini in the mid-1960's, *via* Skylab in the 1970's.

January 1964
Plan for Gemini EVA is published which includes plans to fly an Astronaut Maneuvering Unit on Gemini 9.

August 1964
AiResearch begins work on integrating displays and associated circuitry for the unit into basic design of EVA life support system. Designated as DoD experiment D-12, the AMU was to be constructed by Ling-Temco Vought under sponsorship of the USAF. USAF Major Ed. Givens was assigned to work on project for the USAF (selected as a NASA astronaut in April 1966, he died in a car crash in June 1967).

23 February 1966
AMU for Gemini 9 is delivered to Cape Kennedy. Inspections revealed nitrogen leaks in the propulsion system and oxygen leaks in the oxygen system. Repair work was completed on March 11 and the unit was installed in Gemini 9 March 14–18.

5 June 1966
Gemini 9 pilot Gene Cernan abandons an attempt to don the AMU when his life support system becomes overloaded because of the work involved.

23 September 1966
The AMU intended for Gemini 12 is removed from the craft after NASA HQ cancels AMU experiments after persistent problems in performing EVA on earlier flights.

18 November 1966
NASA suggests incorporating the USAF AMU into the then Apollo Application Program (AAP, later Skylab).

1968
Martin Marietta begin development of an AMU for AAP. The experiment, designated M-509 in 1969, was designed to evaluate three types of EVA propulsion methods inside the pressurised forward dome of Skylab.

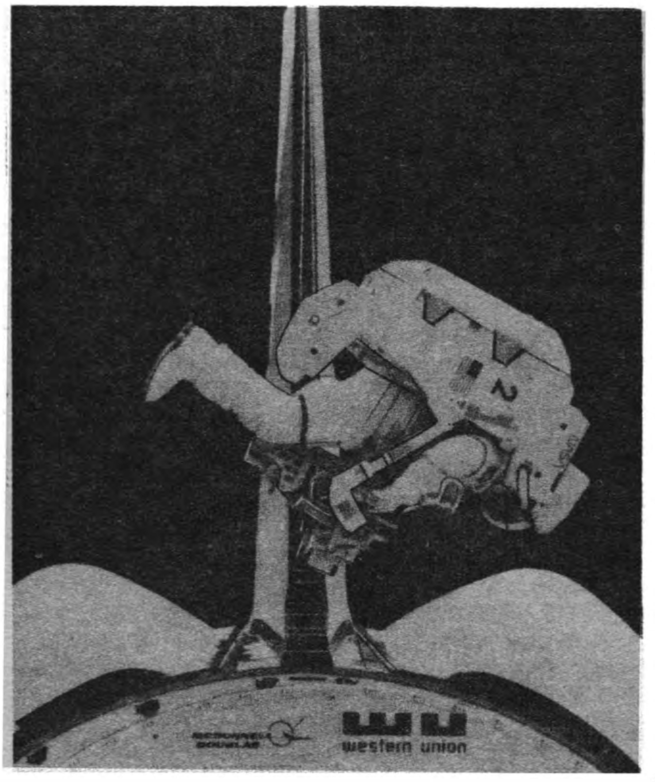
12 August 1973
During flight day 17 of Skylab 3 Alan Bean flies the Automatically Stabilised Maneuvering Unit backpack for 200 min around Skylab's forward dome. Jack Lousma also flew unit for an unscheduled 10 minutes.

14 August 1973
The SL-3 astronauts conduct a second run on ASMU but this time wearing a space suit to simulate an actual EVA exercise.

20 August 1973
Bean flies ASMU for two periods, of 38 and 27 minutes.

26 August 1973
Lousma flies ASMU for 210 mins for its fifth test.

30 August 1973
Science Pilot Owen Garriot, never trained before the mission to use such equipment, flies an unscheduled test of the ASMU. He found the unit easy to control.



Bruce McCandless tests the first MMU. *NASA*

14 January 1974
During the 84 day mission of Skylab 4, astronauts Carr and Pogue conduct tests with the ASMU.

1974-1983
Martin Marietta and NASA develop an astronaut Manned Maneuvering Unit for use by Space Shuttle astronauts. Astronaut representative was Bruce McCandless who had worked on the Skylab ASMU.

September 1983
Two of three Shuttle MMUs are delivered to NASA's Johnson Space Center for acceptance tests. A third unit, designed for qualification testing, remained at Martin Marietta.

November 1983
The two MMUs for use on 41B are installed in *Challenger's* payload bay at the Cape.

7 February 1984
Astronaut Bruce McCandless becomes the first person to conduct an untethered EVA, during the 41B Shuttle mission. In a 6 hour EVA both McCandless and Bob Stewart both fly the unit up to 100 m away from the orbiter (using different units).

9 February 1984
McCandless and Stewart conduct further untethered test flights of the two MMUs in *Challenger's* payload bay in preparation for the 41C Solar Max repair flight.

8 April 1984
Shuttle 41C astronaut George Nelson uses an MMU to approach the Solar Max satellite and attempt a capture; he fails although his MMU works perfectly.

D.J. Shayler

Designated the Normal Corrective (NC-1) manoeuvre, it changed the closing rate to 389 km/hr. By the time the burn was complete, the range to Palapa was down to 24,361 km.

Mission Day 2: 9 November 1984

The second day highlight was the deployment of the Canadian Anik D2 communications satellite. Before it could be released, however, Hauck and Walker fired the OMS engines twice to circularise the orbit at 302 km. These manoeuvres had the dual purpose of setting up the most favourable conditions for Anik's release as well as contributing to the Palapa rendezvous.

The checkout of the Canadian satellite went well and, at 21:05, as *Discovery* crossed the equator midway through its 22nd orbit, the spinning drum-shaped spacecraft was ejected from the payload bay exactly as planned.

As soon as the Orbiter was at a safe distance, some 45 minutes after the deployment, the solid-propellant PAM engine was fired to push Anik into a geosynchronous transfer orbit. The perfect 87-second burn set the satellite up for its eventual positioning over the equator at 111.5°W longitude. Anik was to be put into storage at this location, waiting to come into full service in 1986. Telesat Canada, the owners, took such an unusual move after deciding that it would cost less to launch the spacecraft in 1984 and store it in orbit for two years than it would cost to launch it in 1986 at increased Shuttle rates.

Mission Day 3: 10 November 1984

The deployment of the Syncom 4-1 (Leasat-1) communications satellites was scheduled to be the main activity for the third day. Identical to the Leasat-2 craft deployed in August 1984 by Mission 41D, it was intended to serve as a link between US Navy forces around the globe. Like its sister craft, Leasat-1 was deployed in the 'frisbee' fashion, being kicked out of *Discovery's* payload bay on its side, spinning at 2 rpm, at 12:56.

Forty-five minutes later, after Hauck and Walker again moved *Discovery* away, Leasat's own built-in modified Minuteman 3 perigee kick motor fired to start the satellite on its long trip to geosynchronous orbit.

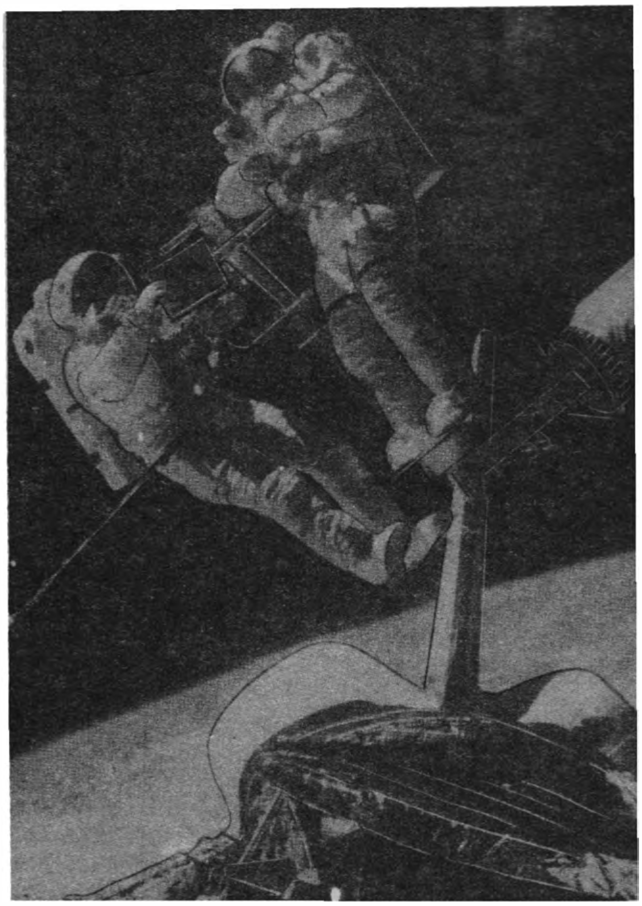
Most of the rest of the day was taken up by a preliminary checkout of some of the EVA gear, mainly by mission specialists Allen and Gardner. This showed up one of the first minor problems of the remarkably trouble-free mission: they could not get the left-hand EVA spotlight on the helmets to work. To the genuine amazement of Mission Control in Houston, it turned out that the batteries were drained on each of the lights. As there were no replacements aboard, the astronauts would have to conduct the EVAs without their benefit.

Mission Day 4: 11 November 1984

In the final day of their long celestial chase, Hauck and Walker performed more rendezvous manoeuvres aiming for a close approach early on Day 5. Palapa was in a 361 km orbit and, by the end of the day, the manoeuvres had steered *Discovery* into a path just 33 km below and only a few hundred km behind the target.

In addition to the rendezvous manoeuvres, Hauck also lowered the cabin pressure in order to make the EVA pre-breathing time shorter for Allen and Gardner.

It was not all work, however, and the crew took time to engage in some playful activities. Much of this centred around Joe Allen who, at 1.67 m and 59 kg, was the smallest and, at 47 years of age, the oldest member of the crew. A running joke throughout the mission had been 'Where's Joe Allen?' Supposedly because of his small size, he kept getting lost. At one point, his empty flight suit floated past the middeck TV camera and the other crewmen professed to not being able to locate him. Later, as if by magic, Dale Gardner appeared to pull Allen out from inside a middeck storage locker, to the amusement of the Earth-bound TV viewers and the laughter of the crew.



Allen and Gardner triumphantly hold a 'For Sale' sign over the two captured satellites at the end of the second EVA. *NASA*

Mission Day 5: 12 November 1984

Throughout the night, *Discovery* had been moving steadily toward Palapa, with each passing orbit closing the gap. Visual acquisition was first made at about 09:00 with the aid of the telescope on the Crew Optical Alignment Sight. Radar acquisition followed about two hours later, providing Hauck and Walker with very accurate information on their range and closing rate.

The final pre-EVA checks went very well and Allen and Gardner emerged into the cargo bay in time to see the slowly spinning blue cylinder of Palapa hovering over their heads just a few hundred metres away. As Hauck and Walker closed the distance down to about 11 m, Allen donned the manoeuvring unit, checked it, donned the stinger and then began his move over to the satellite.

At first, everything went according to plan. Allen's flyover was uneventful and he had no trouble using the stinger to hard-dock himself to the aft end of the satellite, an event which took place at 14:43. He then punched the 'Attitude Hold' button on the manoeuvring unit, permitting Fisher to use the robot arm to grapple the satellite. So far so good.

Gardner got into the foot restraints and Fisher manoeuvred the top end of the satellite down to his work station so that he could fasten the A-frame over the folded dish antenna. However, after Gardner got one side

of the A-frame attached, it popped off as soon as he tried to fasten the other side. After several tries, he gave up, telling Mission Control that a small aluminium piece of a signal transformer on Palapa was protruding just a fraction too high to permit the A-frame to be attached.

Undaunted, the astronauts fell back on Plan B, a scheme they had practised just three weeks before, calling for them to man-handle the satellite down onto the retrieval pallet without the aid of the A-frame. First, the base adapter had to be attached and, in order to do so, Allen had to unfasten himself from the stinger and park the manoeuvring unit, which he did while Fisher kept the robot arm docked to the stinger fixture.

Out of the backpack, Allen came over to help Gardner. With Allen physically holding onto the 574 kg satellite with his hands, Fisher undocked the robot arm so that Gardner could remove the stinger and begin the lengthy job of bolting on the base adapter. Allen held onto the 2.74 x 1.52 m drum for 77 minutes - nearly a full orbit - as Gardner attached the massive adapter.

By 18:00, the ring was fastened on tightly and the two astronauts manoeuvred the satellite down on to the pallet, being careful not to move too quickly. Even though it was weightless, it still had its full half-tonne mass and once the men got it moving it was difficult to stop. Hauck continually reminded them to move it slowly so as not to damage either Palapa or *Discovery*.

After a few bumps, they got it safely clamped down and Palapa became the first satellite to be retrieved for return to Earth. A small number of the solar cells had been damaged from all the jostling around but, aside from that, the satellite was in excellent, and most certainly repairable, shape.

With half of their retrieval work now completed, Allen and Gardner moved back inside *Discovery* after exactly six hours outside.

Mission Day 6: 13 November 1984

Day 6 was programmed as a rest day. The crew re-charged the EVA life support packs, re-checked the equipment, and performed several manoeuvres in advance of the second rendezvous. There was much discussion of possible plans of attack in light of the unexpected problems. Since the two satellites were supposedly identical and the A-frame would not fit on Palapa, was there any reason to think it would be any different with Westar? Since there was such uncertainty, the crew and mission control decided to once again dispense with the A-frame.

The plan was very similar to that used with Palapa, but with some modifications. After Gardner flew over to Westar and stabilised it with the manoeuvring unit, Allen would climb aboard the Manipulator Foot Restraint on the end of the robot arm. From this perch, he would grap the omni antenna mast atop Westar, using it has a handlhold. On the Palapa pickup, the mast had already been cut away by the time the problems occurred, so Allen had had a very awkward time finding places to hold the satellite.

With Allen thus acting as a human A-frame, Gardner would undock from Westar's aft end, fasten the adapter and, hopefully, the two astronauts would then be able to berth the satellite next to its twin in the payload bay.

The crew was very optimistic and at the end of the day Hauck told mission control that they were 'looking forward to Joe and Dale bringing Westar aboard and then coming home three days from now.'

Mission Day 7: 14 November 1984

The second rendezvous was completed just as perfectly as the first. As Hauck and Walker guided *Discovery* closer to the spinning satellite, Gardner and Allen opened the airlock hatch to move outside.

This time Gardner flew the manoeuvring unit over for the capture, an event which took place at 12:32. Meanwhile, Allen mounted the foot restraint and, with Fisher moving him from inside the Orbiter, he successfully grabbed hold of the omni mast, achieving a docking of sorts just after 13:00.

From there, things went quickly and easily. With Allen holding tightly to the antenna, Fisher moved Westar into position while Gardner parked the manoeuvring unit. Gardner then found that he was able to fasten the base adapter with almost no trouble at all. At one point, he accidentally bumped the release button on the tether clamp for the torque wrench and it started to drift away. He quickly grabbed it after Walker called it to his attention.

By 14:42 - more than an hour ahead of schedule - the base adapter was installed. With Allen still holding fast to Westar's antenna, Fisher then used the arm to berth the satellite in the bay next to Palapa. Two very happy spacewalkers then leisurely stowed equipment and tools before going back inside *Discovery* to join their equally-elated comrades after an EVA of 5 hours 42 minutes.

Mission Day 8: 15 November 1984

Traditionally on Shuttle flights, the day before entry is 'cleanup' day and Mission 51A was no exception. Mission specialists Fisher, Allen and Gardner packed all loose items away while pilots Hauck and Walker check on *Discovery's* health to make certain that she was ready for landing.

The crew took a telephone call from President Reagan, who congratulated them on their successful effort, and later they all gathered before the middeck TV camera to take part in a space-to-ground news conference with journalists in Houston. The five astronauts seemed to have trouble realising that they had actually achieved the rescue. Gardner said at one point, 'You know, we've all been looking out the window at those two satellites in the bay and none of us can quite believe we've really got them in there.'

When asked by the reporters what they could possibly do as an encore, Gardner said with a straight face that when he got home he planned to 'pay some bills' and Allen said that he would probably have to 'cut the grass.' Such is the life of an astronaut.

Predicted weather conditions for the Kennedy Space Center were good and all was in readiness for *Discovery's* landing at the Florida site at 11:59 the next day.

Mission Day 9: 16 November 1984

For a time there was some concern about low clouds at the Kennedy site, but with weather forecasts indicating things would clear up by landing, mission control gave Hauck a 'GO' for the OMS deorbit manoeuvre.

The two engines were ignited on time over the Indian Ocean and the spaceplane streaked across the Pacific and the southern United States as air resistance steadily decreased its velocity from nearly Mach 25 down to subsonic speed in little more than half an hour. At 11:57, observers at Kennedy heard the familiar double sonic boom as *Discovery* decelerated through Mach 1. The Orbiter then flew a wide left turn out over the Atlantic and back towards the landing facility as the automatic controls lined *Discovery* up perfectly with Runway 15.

In routine fashion, Hauck then took over manual control and dropped the Orbiter out of the sky to make the third Kennedy Shuttle landing, at 11:59:56. *Discovery* and her cargo of five astronauts and two salvaged satellites were home after a flight lasting 7 d 23 h 44 m 56 s.

THE JOHNSON SPACE CENTER

By Curtis Peebles

Renowned as the home of the astronauts, the Lyndon B. Johnson Space Center has a long and varied history. Although not formally established until the early 1960's, the events that shaped it go back to the period before the founding of NASA. Looking ahead from the mid-1980's, there are the challenges of developing and operating the permanent US Space Station.

The Langley Years

The pre-history of the Johnson Space Center (JSC) can be traced back to the early and mid-1950's. With larger rockets available to provide thrust, engineers and scientists of the National Advisory Committee for Aeronautics (NACA) realised that the way to space was open. This feeling was particularly strong at the Langley Aeronautical Laboratory - the oldest NACA centre having been formally dedicated on 11 June 1920. Its location near Hampton, Virginia was originally selected for a variety of reasons. The weather was good for flying, the land was flat and, being near the Atlantic, tests could be made over both land and sea. It was readily accessible from Washington, DC and, being near Norfolk Naval Base, was believed to be safe from attack or capture in the event of war.

Langley had several reasons for an interest in space. Many of the personnel had experience using aerofoils mounted on the wings of aircraft and rocket-launched scale models for research. Another reason was the large amount of space-related work done at Langley: 90% of the Pilotless Aircraft Research Divisions effort and 40% of the rest of the laboratory's work dealt with space - the highest percentage of any NACA centre. Many of the concepts used in Project Mercury were first developed at Langley in the years immediately before and following Sputnik. In the spring of 1958, manned spacecraft research at Langley was placed under the direction of Robert Gilruth. In November 1958, a month after NACA became NASA, this was formally organised as the Space Task Group. Some of the people directly or indirectly involved were: Maxime Faget, Christopher Kraft, George Low and Abe Silverstein.

Judith Resnik during training for the 41D Shuttle mission. An astronaut spends a year in general training then up to a year working on a specific mission. *NASA*

The astronauts of the first Shuttle group are briefed on the workings of Mission Control in 1979. *NASA*

Following their selection in April 1959, the first seven Mercury astronauts joined the Space Task Group. Once at Langley, they began a series of briefings, lectures on space science and other training exercises; for example, considerable time was spent in the two Mercury simulators - one at Langley, the other at the Cape. Between such trips, Langley would serve as home base.

The Move to Houston

The Space Task Group had started with only 35 people working out of the Unitary Wind Tunnel Building but the demands of developing the first US manned spacecraft saw it grow explosively. By January 1960, with the first launch still a year away, it had over 500 members. By mid-1961, this had risen to 794. The Space Task Group could no longer be considered an appendage of Langley. Within days of President Kennedy's May 1961 commitment to land men on the Moon, word began to circulate that there would be a move to a new centre. One possibility that had been considered earlier but then eliminated was the Beltsville Center in Maryland (now known as the Goddard Space Flight Center). Staying at Langely was not possible since the manned space personnel would have eventually dominated the facility to the detriment of its aeronautical research.

In August 1961, these rumours became reality when a survey team was formed to recommend a location for a manned spacecraft centre. In evaluating some 20 possible sites, the committee used 10 criteria: availability of universities and other scientific facilities, electrical power, water supply, climate, housing, acreage, local industry,

Johnson Space Center in October 1978. Note the Saturn 5 at bottom left, one of only two flight vehicles remaining (the other is at the Kennedy Space Center). *NASA*

air and water transportation and local recreational and cultural resources. On 19 September 1961, NASA Administrator James Webb announced that Houston in Texas had been chosen. It was questionable that Cape Canaveral met the requirements. As stated, the selection criteria realistically required a location near a large city rather than a small town/rural area like the Cape.

The chosen site was 40 km southeast of downtown Houston near Clear Lake, on 1020 acres donated by the Rice Institute of Technology and the Humble Oil Company; another 600 acres were bought for $1.4 million. The land was flat, brush-covered and inhabited by cattle, wolves, wild turkeys, foxes and deer. Personnel began moving from Langley in October 1961 into rented quarters in and around Houston.

'Roger, Houston'

Construction at the new site began in April 1962 and personnel began moving into it during March 1964. For the first decade of operations, it was known as the Manned Spacecraft Center but on 17 February 1973 it was renamed the Lyndon B. Johnson Space Center. President Johnson had been a moving force behind the US space programme: as a Senator, he had been an early supporter of a civilian space agency and, as Vice President, he had recommended a manned lunar landing as a method of challenging the Soviet space successes. Finally, as President, he had continued to provide support.

The Center has the responsibility for all aspects of the development, management and control of US manned space flights. This requires a wide variety of facilities, the most famous of which is Building 30, better known as 'Mission Control.' The first flight directed from Houston was Gemini 4 in June 1965 - previously missions had been controlled from the Cape but Houston now takes over once the booster clears the launch pad tower. In the 20 years following Gemini 4, television views of Mission Control's row of consoles have become familiar but, ironically, visitors on tours are often surprised on seeing it in person: the wide angle television lenses make it appear larger than it really is.

Another part of Mission Control is the support rooms. Here, the experiments and payloads can be monitored and specialists can work out solutions to any problems that may appear. Tying the whole network together are banks of computers.

Another key facility is the mission simulators in Building 5. Astronauts spend many hours practising both mission activities and emergency procedures. On the Shuttle, for example, the breakdown is 15% mission, 85% emergencies. For some emergency exercises, the simulators are linked with Mission Control since the flight controllers must be ready for any emergency as much as the astronauts. The simulators are also used for mission planning and systems testing and development.

Similar training aids are the full scale spacecraft mock-ups, used for instructing the crew in habitability, EVA, entering and leaving the spacecraft, television operations, waste management, stowage and routine housekeeping and maintenance. For the Shuttle, these mock-ups, in building 9A, include a forward fuselage, the remote manipulator system task trainer (with an arm and rear cabin) and a forward fuselage with an attached payload

bay. Astronauts use helium-filled payload models to practice using the arm.

In addition to training, JSC also tests space components. Building 14 is the Anechoic Chamber Test Facility for communications work; basically it is a room with walls, ceiling and floor completely covered with foam to absorb any stray radio signals. Building 32 is the Space Environment Simulation Laboratory, with two vacuum chambers - one large enough to hold a complete Apollo spacecraft along with high intensity lights to simulate the heat of the Sun and refrigeration equipment to duplicate the chill of space. Another is Building 49: the Vibration and Acoustic Test Facility, used to determine the ability of equipment to endure the pounding noise of launch.

Over the years, test requirements have changed. An example is the varied history of the Flight Acceleration Facility in Building 29 which, when built in the 1960's, contained a centrifuge where astronauts spent unpleasant periods enduring the acceleration profiles of Apollo re-entries. In the 1970's, it became a museum exhibit, displaying Shuttle models and a Lunar Landing Training Vehicle *in* the centrifuge chamber. With the Shuttle, a centrifuge is not needed since launch and re-entry g-loads are less than those on some fairground rides. Now, the centrifuge has been removed and a water tank built in its place for EVA training, large enough to hold a Shuttle flight deck and payload bay.

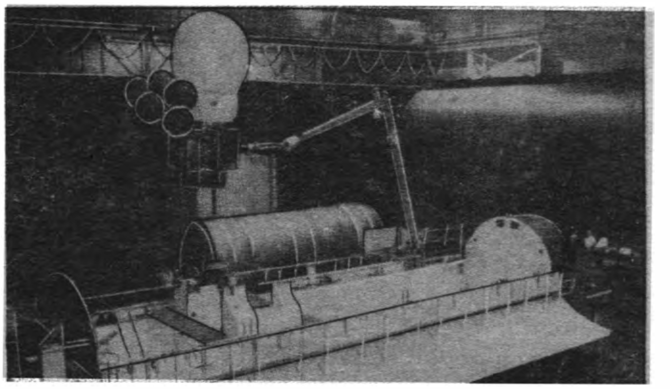
Another changed facility, is Building 37: the Lunar Receiving Laboratory. It was originally designed as a quarantine facility for the astronauts, spacecraft and lunar samples after their return from the Moon so that any lunar bacteria carried back with them would not escape into the atmosphere. The quarantine was soon dropped and the Laboratory's function became a storage facility for lunar samples to preserve them from contamination or damage.

In the course of a year some one million people will visit JSC. Building 2, renamed in the summer of 1981 as the Olin E. Teague Visitors' Center, serves as a museum. When it opened in 1964, it operated for only half days on Sunday but this soon became all day Sunday and then all week-end and, finally, every day except Christmas. The centre has such exhibits as a Lunar Module, the Apollo 17 Command Module, Mercury 9, Gemini 5 and numerous other small displays. Outside are a Saturn 5, a Little Joe II, a Mercury Redstone, a boiler-plate Apollo and several rocket engines. In Building 5 is a complete set of Skylab hardware.

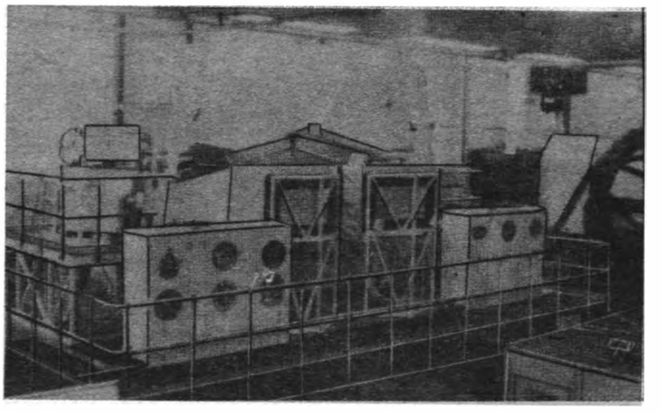
JSC is also involved with several other facilities. One is the worldwide network of tracking stations including the TDRS satellite orbited by STS-6 in April 1983 and its ground station. Another is the nearby Ellington Air Force Base where the T-38s used by the astronauts for transportation are based, as is the KC-135 used for zero-g training. During the Apollo era, Ellington was also used by the Lunar Landing Training Vehicles, with a simulated lunar surface for the astronauts to practise landing in helicopters at different angles and speeds under varying lighting conditions. JSC also operates the White Sands Test Facility in New Mexico.

JSC in the Future

With the decision to develop a permanent US Space Station, JSC moves into a new phase. It has overall programme management and is responsible for the contractors selected to build the station's framework and install systems on the structure. It will also manage the docking system, the station's remote manipulator arm used to assemble the modules, the data management system, the attitude control system, the thermal control



The robot arm trainer in building 9A is one of several Shuttle simulators. Helium-filled balloons are used to simulate zero-g; this picture shows work for the Solar Max satellite repair mission of April 1984. *NASA*



The Shuttle simulator represents the cabin in flight. It can be moved to simulate launch and reentry. *NASA*

system, EVA and the crew ward room and galley module.

As part of this effort, a mock up of a Space Station module was built at JSC, with a ward room, exercise space, sleeping area and showers. Both horizontal and vertical orientations are used and the module resembles a longer version of the Spacelab module.

The Space Station has raised the issue of JSC's future. In late 1981 and again in 1984, NASA Deputy Administrator Hans Mark recommended that Shuttle mission control be transferred to the Kennedy Space Center. He argued that mission control of the Space Station would be more demanding than that of the Shuttle and that keeping the Shuttle at JSC would cost too much and take up too much effort. Mark's suggestion raised questions about what the move would entail, especially if the astronaut office and numerous simulator facilities would also go. NASA Administrator James Beggs has agreed to transfer some Shuttle activities to the Cape over the next several years but, at present, Mission Control will remain in Houston.

Despite such issues, the Space Station seems to be JSC's long term future since it is designed for an operating lifetime of 20 to 30 years. Over that time, the station would be expanded by 'plugging in' new experiments and systems. One estimate is that it will require nine Shuttle launches to orbit the station components, including four modules (two experimental and two living areas). Construction would begin in 1987 with the station ready in the early 1990's, possibly by 1992 in time for the 500th anniversary of Columbus' arrival in the New World.

Acknowledgements

The author would like to thank the Public Affairs Office of the Johnson Space Center for their kind help in the preparation of this article.

SEATING FOR SPACE

By James Oberg

It is obvious where the commander and pilot sit during a Space Shuttle mission, but where do the rest of the crew sit and what roles do they play while seated?

Introduction

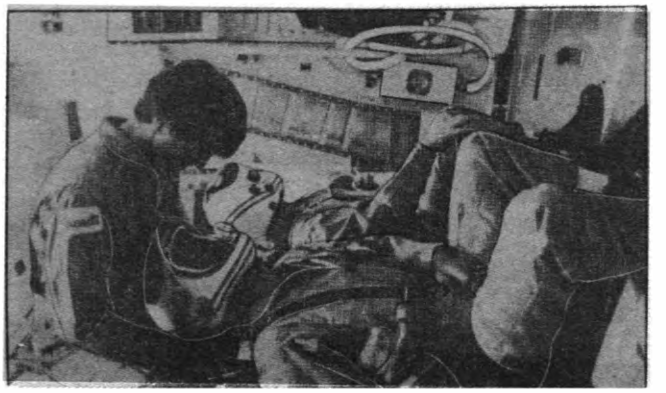
Seating arrangements for the CDR (commander) and PLT (pilot) on a Shuttle flight are the standard left and right positions, respectively. There is a third place that has a function during launch and landing - it can be called the 'flight engineer' position. This astronaut sits in the aft flight deck centre seat. He/she is an integral part of the ascent/entry flying crew (main responsibility: checklists) and is usually MS2 (Mission Specialist 2). MS1 (prime specialist for on-orbit mission operations) sits in the aft flight deck right seat.

As needed, up to four seats can be mounted downstairs on the middeck (only *Atlantis* was built for all four; all the others were built for three and the fourth set of brackets will have to be added). On orbit, both aft flight deck seats and all middeck seats are dismantled and stowed.

There is no obvious way of telling which of the crewmen fill which MS slots; that is generally decided by the mission commander after the crew has been assembled. Furthermore, two from every crew must be trained in spacewalking in case the payload bay doors need to be closed manually. One or two of the crewmembers must be trained in operating the remote manipulator arm if it is carried.

For the four Orbital Flight Test missions in 1981-2, the two-man crew had to be able to do everything. They all learned to perform spacewalks, although none had to do so; the last three pairs of astronauts mastered the use of the robot arm, and all gained experience. But then, with STS-5 in November 1982, things began to get both simpler (for each individual) and more complicated (for the crew as a whole).

There is no accepted standard seat numbering scheme, so the following is adopted here: 1=CDR; 2=PLT; 3=MS2(FE); 4=MS1; 5=MS3/PS; 6=PS; 7=PS; 8=PS/rescue-1; 9=rescue-2 and 10=rescue-3.



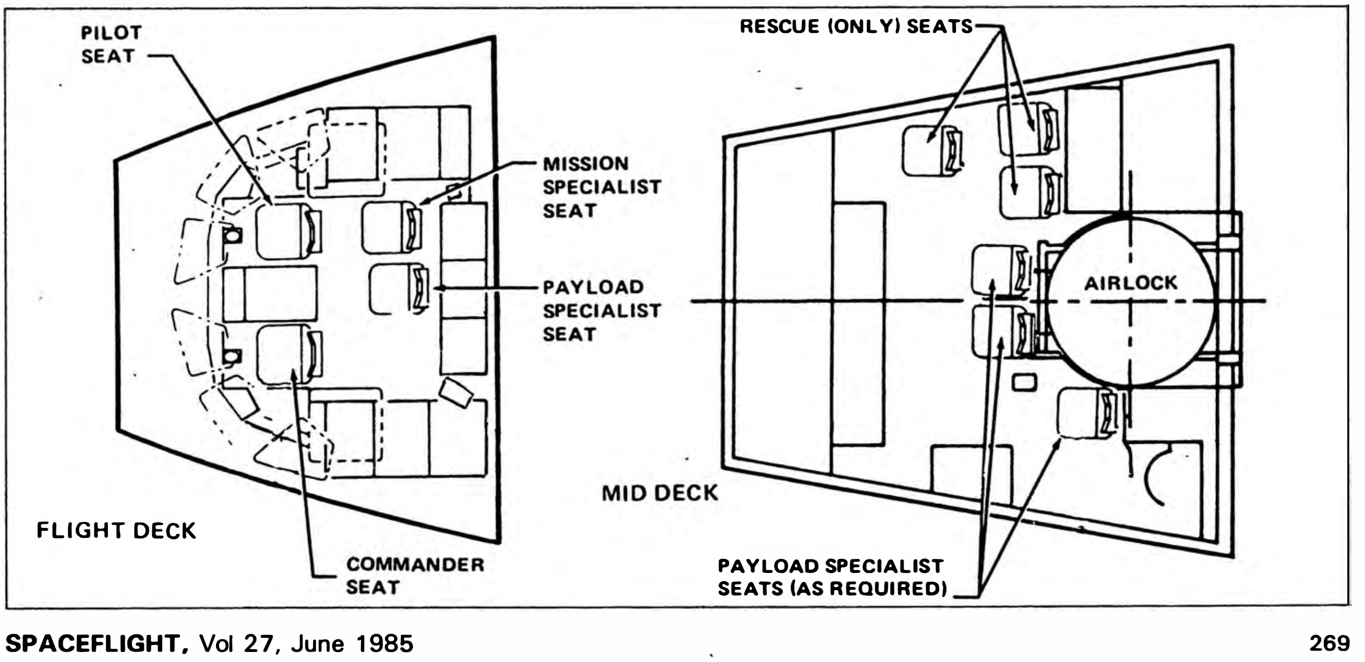
Two middeck seats for Mission 41G. NASA

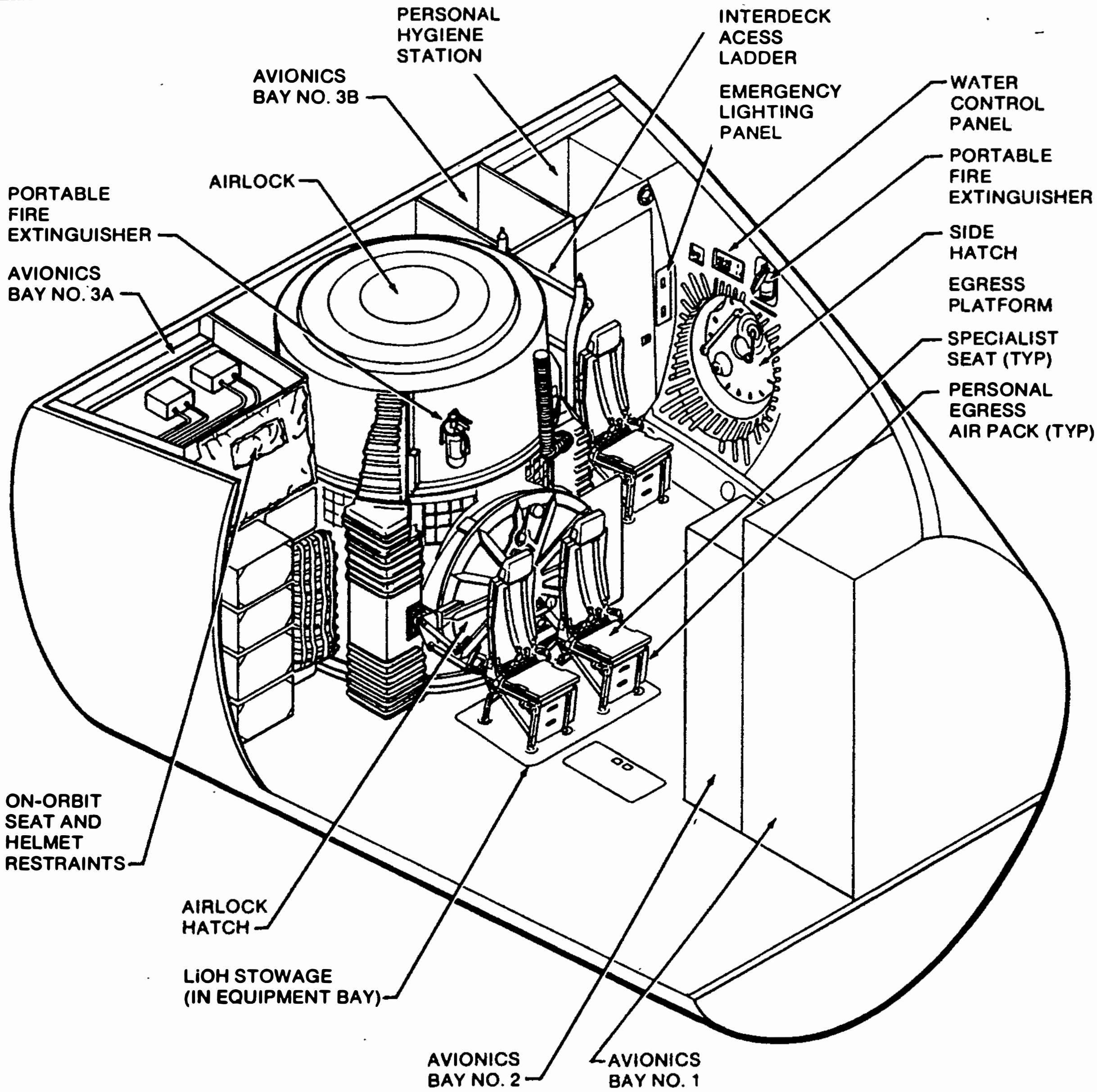
There is a possible future seating variant of: 1=PLT1; 2=PLT2; 3=MS1(FE), 4=CDR; 5=MS2; 6=MS3/PS; 7=PS and 8=PS.

Also, for Space Station relief missions, the Shuttle can carry four to seven passengers besides the flight crew of three.

It turns out that crewmembers do not necessarily remain in the same seat for launch and landing. Lenoir and Allen developed the ascent/entry swap arrangement for STS-5 and it has become the usual, but not universal, practice. An interesting modification of plans occurred on STS 41D when two astronauts were scheduled to occupy the middeck. For convenience, seats 6 and 7 were supposed to have been used, with seat 5 left as open space to allow easier access. However, seat 5 has a view through the hatch window that seat 6 does not and the astronaut assigned to seat 6 objected to losing the chance for sightseeing. So seats 5 and 6 (and not 6 and 7, as planned) were occupied for launch and landing.

The issue of an eighth crewmember first came up on Spacelab 3 during the process of selection of two of the four payload specialists. Since both van den Berg and Johnston were so highly qualified it was suggested that both should fly, using an eighth seat be added. But that would have required qualfication of seat-8's attachment points to the middeck floor and would also have interfered with the placement of the bunks so the suggestion was dropped. Spacelab D1 is the first mission on which eight seats will be installed and the seat will (this time only) be installed *not* at position 8 ('rescue 1') but forward of seat 5.

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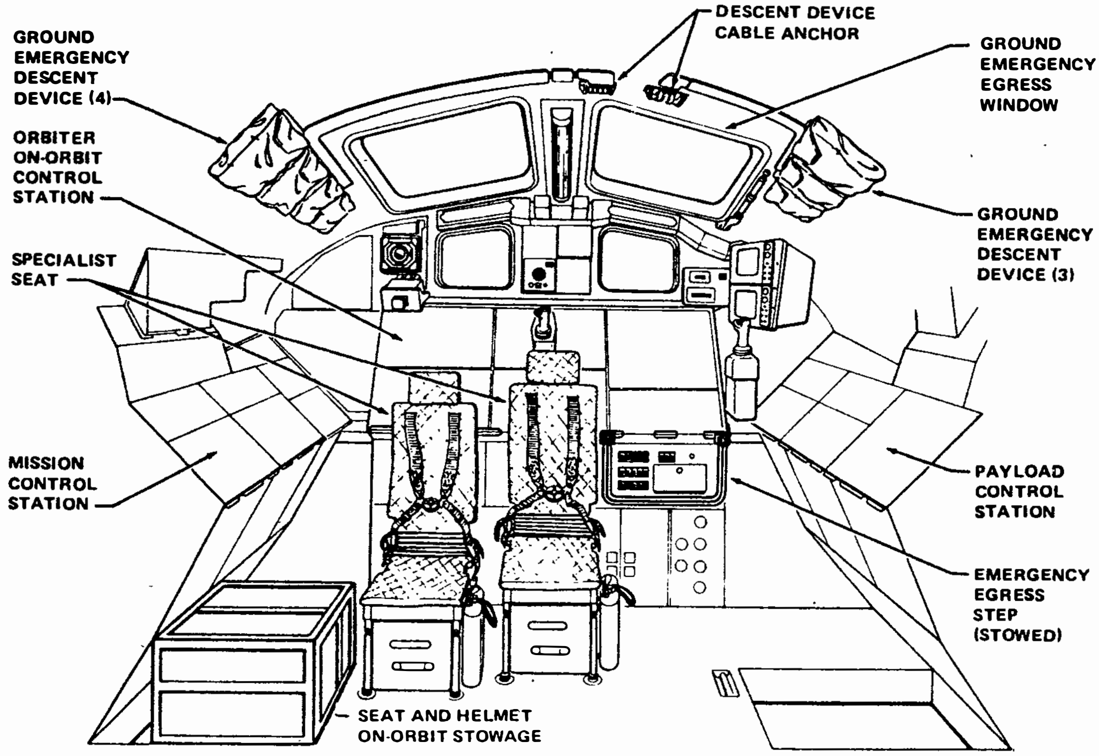
INTERDECK ACESS LADDER
AVIONICS BAY NO. 3B
EMERGENCY LIGHTING PANEL
WATER CONTROL PANEL
PORTABLE FIRE EXTINGUISHER
AIRLOCK
PORTABLE FIRE EXTINGUISHER
SIDE HATCH
AVIONICS BAY NO. 3A
EGRESS PLATFORM
SPECIALIST SEAT (TYP)
PERSONAL EGRESS AIR PACK (TYP)
ON-ORBIT SEAT AND HELMET RESTRAINTS
AIRLOCK HATCH
LiOH STOWAGE (IN EQUIPMENT BAY)
AVIONICS BAY NO. 2
AVIONICS BAY NO. 1


DESCENT DEVICE CABLE ANCHOR
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GROUND EMERGENCY EGRESS WINDOW
ORBITER ON-ORBIT CONTROL STATION
GROUND EMERGENCY DESCENT DEVICE (3)
SPECIALIST SEAT
MISSION CONTROL STATION
PAYLOAD CONTROL STATION
EMERGENCY EGRESS STEP (STOWED)
SEAT AND HELMET ON-ORBIT STOWAGE

SPACE SHUTTLE ASSIGNMENTS

The following codes are used

1: Seat-swap, ascent/entry, with given assignments for ascent (reverse for entry).
2: EVA-trained crewmember (two per mission).
3: MMU-trained crewmember.
4: RMS-trained crewmember.
XXXX: No aft flight deck right seat (*Columbia* only, retrofitted after STS-9).

For EVA and MMU, an asterisk following the code indicates that the function was actually performed. Most EVA training is for contingency only.

[] represents shift designations (if none, the whole crew sleeps simultaneously); this is usually only for Spacelab missions, and the CDR traditionally 'floats' among both shifts.

STS-1 (Apr 1981)
Young(2) Crippen(2)

STS-2 (Nov 1981)
Engle(2,4) Truly(2,4)

STS-3 (Mar 1982)
Lousma(2,4) F'ton(2,4)

STS-4 (Jun 1982)
Mattingly(2,4) H'field(2,3)

STS-5 (Nov 1982)
Brand Overmyer
Lenoir(1,2) XXXX
none Allen(1,2)
(First middeck position)

STS-6 (Apr 1983)
Weitz Bobko
Musgrave(2*) Peterson(2*)
(Musgrave stood up during entry)

STS-7 (Jun 1983)
Crippen Hauck
Ride(4) Fabian(2,4)
Thagard(2)
First 'seat-5'

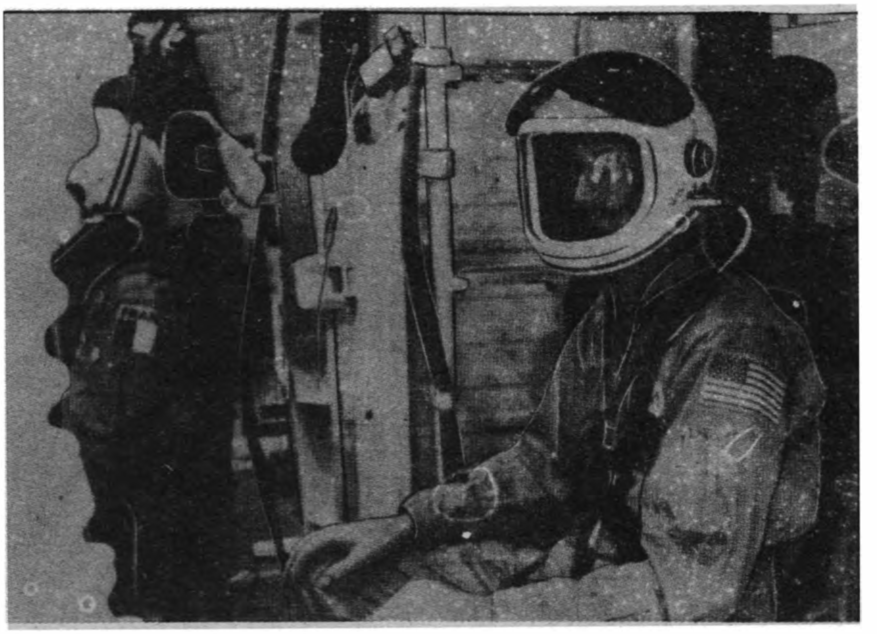
STS-8 (Aug 1983)
Truly(2,4) B'stein
Gardner(2,4) Bluford
Thornton
(Thornton was a 'pseudo-PS')

STS-9 (Dec 1983)
Young(2) [Shaw]
Parker XXXX
[Garriott 2] L'berg
[Merbold]
(First middeck trio and two-shift ops)

41B (Jan 1984)
Brand Gibson
Stewart(2*3*) McNair(4,1)
McCandless(2*,3*,1)
(First seat 4/5 swap)

41C (Apr 1984)
Crippen Scobee
V'Hoften(2*,3*) Hart(1,4)
Nelson(2*,3*,1)
(Solar Max Repair)

41D (Aug 1984)
H'field(4) Coats
Hawley(2) Mullane(2,1)
Resnik(1,4) Walker, C.
(First middeck duo)



Mission Specialist Jeffrey Hoffman occupies the seat in front of the toilet area during training for 51E last November. Immediately to his right is the ladder to the flight deck, behind which is the airlock. Also visible in this picture, taken through the hatch, is Patrick Baudry, sitting in front of the airlock. *NASA*

41G (Oct 1984)
Crippen McBride
Ride(4) Sullivan(2*,1)
Leestma(2*,1) Scully-Power
Garneau
(Seven-member crew)

51A (Nov 1984)
Hauck(4) Walker, D.
Fisher, A.(4) Allen(2*,3*)
Gardner(2*,3*)

51C (Jan 1985)
Mattingly Shriver
Buchli(2) Onizuka(2)
Payton
(DoD mission with IUS stage)

51E Mar 1985 (cancelled)
Bobko Williams
Griggs(2) Seddon(1,4)
Hoffman(2,4,1) Baudry
Garn
(Congressman)

51D (Mar 1985-largely replaced by old 51E crew)
Br'stein Creighton
Nagel(2) Fabian(2,1,4)
Lucid(1,4) Walker, C.
Jarvis
(Jarvis is a Hughes Co. PS)

51B/Spacelab 3 (?Apr 1985)
Overmyer Gregory(2)
Thagard(2) Lind
Thornton Wang
van den Berg

51G (?Jun 1985)
Engle Covey
Lounge V'Hoften(2,1,4)
Fisher, W.(2,4,1) PS
(Arab PS)

51F (Spacelab 2)
Fullerton [Bridges]
Musgrave (2,1) [Henize(4)]
England (4,2,1) [Acton]
Bartoe

51I
Shaw O'Connor
Cleave Ross(2,1)
Spring(2,1) Konrad
Walker, C.
Standby (51J)
Bobko Grabe
Stewart(2) Hilmers(2)
AF-PS?

Spacelab EOM-1 (Cancelled)
Brand Smith
Springer(2) Garriott(2,1)
Nicollier(1) Lichtenberg Lampton

61A (Spacelab D1)
H'field [Nagel(2)]
Buchli(2) [Dunbar(1)]
Bluford(1) [Furrer]
M'schmid Ockels

61B
Gibson Bolden
Hawley Nelson (2,1)
Chang(2,1) PS?

51L
Scobee Smith
Resnik Onizuka (2,1)
McNair (2,1) PS?

61C
Coats Blaha
Fisher, A.(4) Springer(1,2)
Thagard (1,2)

Spacelab 4
Brand Griggs(2)
Fabian(2,4) Seddon(1,4)
Bagian(1) PS-1/PS-2

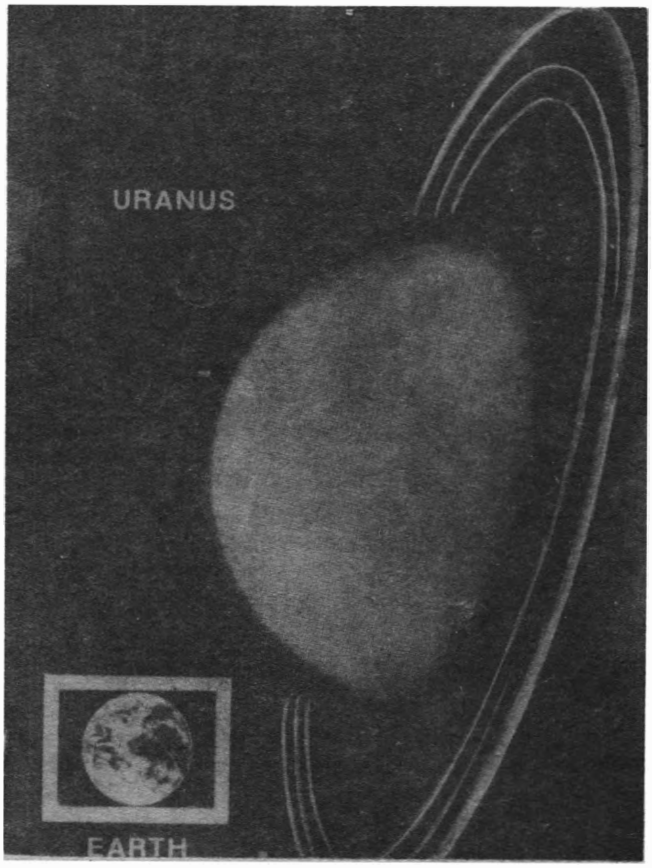
62A (VOFT-1)
Crippen Gardner, G.
Gardner, D.(2) Mullane(1)
Ross (2,1) AF-PS?
(First Vandenberg Orbital Flight Test)

Spacelab Astro-1
McBride Richards
Leestma(2) Hoffman(2)
Parker PS-1/PS-2.

THE RINGS OF URANUS

The present concept of the rings of Uranus is that of nine sharp-edged ringlets. The ring particles follow inclined, eccentric ellipses that precess due to the gravitational field of Uranus. As particle collisions would broaden narrow rings in a time much shorter than the age of the Solar System, the system of rings either formed recently or is prevented from spreading. With no apparent evidence for recent formation and with no rings showing a tendency to broaden, it is assumed that the rings are confined by forces produced by nearby satellites, as is the case in the Voyager discovery of two satellites 'shepherding' the F ring of Saturn. No such satellites have been observed. The ring particles themselves appear to range from 0.1-10 mm. J.L. Elliot, R.G. French, K.J. Meeds of the Massachusetts Institute of Technology, writing in 'Structure of the Uranian rings. I. Square-well models and particle-size constraints.' *Astronomical Journal* **89**, 1587-1603, 1984 commence an investigation of possible orbit perturbations by shepherd satellites by instigating an analysis of the occultation profiles of the rings. This would enable comparisons to be made of ring structure and kinematics with dynamical models. For instance there appears to be a longitudinal clumping of ring material which may be due to longitudinal waves excited by shepherding satellites.

Earth and Uranus compared. NASA



By Prof. John Griffith of Lakehead University, Ontario, Canada.

THE GIANT PLANETS

In his presidential address to the Royal Astronomical Society, R. Hide of the Geophysical Fluid Dynamics Laboratory, Meteorological Office, discussed Jupiter and Saturn. Hide's main interests are in the circulation of their atmospheres, their interior structure and the origin of their magnetic fields. In the *Quarterly Journal of the Royal Astronomical Society* **25**, 232-247, 1984, he reminds us that the most massive planet, Jupiter, has a mean density less than a quarter that of the terrestial planets and consists mainly of hydrogen - although throughout the planet the high pressure has compacted the hydrogen into its metallic form, becoming a good conductor of electricity.

The outer clouds of Jupiter consist of hydrogen, helium, methane, ammonia and other gases. The striking and variable colours are probably due to the presence of products of the photolysis of NH_3, H_2S, PH_3 and other compounds by solar ultraviolet light.

Jupiter has a strong dipole magnetic field, with an associated system of van Allen-type 'radiation' belts of electrically charged particles extending beyond and interacting with its innermost Galilean satellite, Io.

Jupiter rotates faster at the equator than at the poles, leading to a variety of fascinating scientific problems in considering the dynamics and magnetohydrodynamics of its atmosphere.

Jupiter's magnetic field is about 10,000 times the strength of that of the Earth, and it has been proposed that, like the Earth's, it is due to electric currents circulating in conducting regions within the planet.

The planned 1986 launch by the Shuttle/Centaur of the Galileo spacecraft should lead, in 1988, to our first long-term close observations of the Jovian system, together with an entry probe to give our first *in situ* measurements of Jupiter's atmosphere.

STELLAR CIVILISATIONS

The limits of growth in a finite system, which are naturally imposed on all civilisations within the Galaxy, are shown to be the overwhelming constraint affecting their natural selection. It is claimed that, as a result, the entire Galaxy will become populated by stable, highly ethical and spiritual civilisations.

M.D. Papagiannis of Boston University, writing in *Quarterly Journal of the Royal Astronomical Society*, **25**, 309-318, 1984, starts his discussion by examining the evolution of matter, of life and of intelligence and technology.

He reminds us of the problems facing our civilisation today: overpopulation, a diminishing food supply, pollution and destruction of the environment, thermal pollution and the dangers of nuclear self-destruction. Are such problems associated with every technological civilisation and is the ultimate crisis inevitable? We have less than a century to stop expanding and polluting. Discovery of additional

NGC 6744, a type Sc spiral galaxy in the constellation of Pavo. *Kitt Peak*

energy sources would not avert the thermal pollution problem, nor would it necessarily provide a more equitable distribution of wealth.

Emigration into space would not solve the problem - how do we launch 200,000 people a day without drastically affecting our economy and without pollution of the atmosphere?

Papagiannis sees the development by a small number of people of well-planned, self-sustained space colonies isolated from the final fate of our planet. He sees almost unlimited space and resources for expansion with plenty of energy available. However, he points out that, ultimately, even an initially small colony in our Solar System will come up against problems of lack of mass.

Then he turns to interstellar travel and colonies around other stars. In between 10 to 100 Myr the entire Galaxy will be populated. He points out that interstellar travel is very expensive - at a speed of 0.1 c the energy requirement would, at present prices, cost around £1 million for the transportation of 1 g.

He concludes by pointing out that bringing about a halt to population growth and materialistic expansion 'requires a society of unselfish individuals disinterested in personal wealth and power.' This is a form of natural selection, ensuring that long-surviving stellar civilisations have chosen intellectual values over materialism. Life has finally entered a stage of moral and spiritual evolution. Stagnation would be countered by intellectual pursuits, and ultimately every suitable star will be populated by a stable stellar civilisation in a high level of ethical completion. All other types will have self-destructed. 'If ever we were to make contact with another stellar civilisation, it will most probably be a peaceful, kind and ethical one, of which we have nothing to fear, rather than the evil and belligerent type we usually find in science fiction stories or popular movies!'

Papagiannis ends by stating that if evolution leads to the moral and spiritual evolutionary stage that he is proposing, then creation has evolved towards a rational goal, with beings 'with enough spirituality to be in close communication with the Creator.' The process of evolution leads to a deduction by scientific reasoning of 'a Creator who through the process of evolution is creating people in its own image and likeness to inherit the world.'

CLOSE ENCOUNTERS

Computer simulations of close encounters between a planet-star system and a stellar intruder were found often to lead to disruption of the planet-star system. If disruption did not occur, close encounter usually led to the intruder capturing the planet. These simulations were applied to situations in the neighbourhood of the Sun, the galactic centre and globular clusters.

J.G. Hills, writing in 'Close Encounters between a star-planet system and a stellar intruder,' *Astronomical Journal*, **89**, 1559-1564, 1984, reports on the results of around 40,000 computer simulations.

Hills comments that, in 4 x 10^9 years time, as the Sun begins to leave the main sequence of its giant phase, it may be possible by means of an engineered close encounter to replace the Sun by a younger star!

He also deduces from the present low values of orbital eccentricity for the planets that no stellar intruder has passed within 40 AU of the Sun since the formation of the planetary system. However, the impact upon the cometary cloud of a star passing within a few thousand AUs of the Sun may produce an enormous shower of comets. It may be difficult to distinguish such a bombardment from the effects of the hypothetical solar companion Nemesis (see *Nature* **308**, 713, 715 and 718, 1984).

For stars in the interior of a globular cluster, the break up of planetary systems is highly probable. In the galactic centre most planetary systems would long ago have disassociated, forming unbound planets wandering among the stars.

SUPERNOVA REMNANTS

The evolution of supernova remnants powered by the central pulsar has been considered by several authors. After the supernova explosion has disrupted the star, with the core imploding to form a pulsar, it is expected that a strong radio emission, lasting for a time of the order of magnitude of the initial slowing-down time scale of the pulsar, would be followed by a gradual decay.

Now that there are several galactic remnants resembling the Crab Nebula, probably driven by a central, undetected, pulsar (termed plerions - see Weiler, K.W. in I.A.U. Symposium 101, *Supernova Remnants,* Reidel, p.299, 1983) the interest in the study of pulsar-driven supernova remnants has increased.

R. Bandiero of the European Southern Observatory, F. Pacini of the Arcetri Astrophysical Observatory and M. Salvati of the Istituto di Astrofisica Spaziale, in 'The evolution of non-thermal supernova remnants. II Can radio supernovae become plerions?' *Astrophysical Journal,* **285,** 134-140, 1984, use our present knowledge of pulsar electrodynamics to establish a plausible link between radio supernovae and plerions.

Several extragalactic supernovae have been detected in the radio band some time after the optical outburst. The authors give a table of the properties of the five known radio supernovae, where the presence of a central pulsar is not definite. With the assumption that a pulsar is indeed present, the authors examine the consequence of the circum-pulsar nonthermal bubble, which evolves into the plerion. Their model is chosen to fit the radio data but does not agree with the high-frequency emission.

COMPACT BINARY SYSTEMS

Even though the physical presence of binaries in globular clusters is difficult to detect observationally, theoretical considerations indicate that they are of considerable importance in globular cluster evolution. Binaries in globular clusters will probably be detected through phenomena associated with mass transfer on to collapsed stellar remnants. Certainly the number of bright X-ray sources in globular clusters is anomalously large, presumably as the result of mass transfer onto neutron stars or degenerate dwarfs. Julian H. Krolik of the Harvard-Smithsonian Center for Astrophysics, in his paper entitled 'The appearance, number and history of highly compact binary systems in globular clusters,' *Astrophysical Journal,* **2892,** 452-465, 1984 and in the following paper, co-authored with A. Meiksin and P.C. Joss, 'The evolution of highly compact binary stellar systems in globular clusters,' *Astrophysical Journal,* **282,** 466-480, 1984 consider this problem.

In the first paper he examines the variety of conditions in which accreting collapsed stellar remnants can find themselves within globular clusters. If mass is being transferred from a red dwarf to a degenerate dwarf or neutron star, then the creation rates and life times will be changed by the high stellar densities within a globular cluster. Other collapsed remnants within clusters may accrete from massive discs arising from catastrophic gravitational encounters. The author constructs an analytic model to predict the number of accreting degenerate dwarfs and neutron star in globular clusters, with the number roughly proportional to the product of the cluster's core density and mass. The predictions are in reasonable agreement with observations.

The second paper looks at the effect of a globular cluster on the evolution of a highly compact binary stellar system. Field stars drive the binary components together more rapidly than if the system were evolving in isolation. Some close encounters lead to the secondary being ejected and replaced by the field star, and the interaction may also lead to a rapid transfer of mass (of the secondary or of the field star) to the primary.

A collision leads to a disruption of any non-collapsed star, with a large mass transfer to the collapsed star, probably with formation of a massive accretion disc. Systems may even be expelled from the cluster. Certainly luminous X-ray sources are expected to result from collisions.

CLUSTER OF GALAXIES

The dynamical evolution of the systems of globular clusters of galaxies within clusters of galaxies shows that, eventually, small galaxies lose clusters and large galaxies gain, with a number ending up as intergalactic globular clusters. There should be a high degree of homogeneity among the outer halos of the more massive galaxies of a cluster.

Globular clusters are compact, spherically symmetrical groups of thousands to tens of thousands of older Population I stars surrounding the disc of galaxies in the galactic halo.

J.C. Muzzio, R.E. Martinez and M. Rabolli of Argentina, in their paper 'Globular cluster swapping in clusters of galaxies,' *Astrophysical Journal,* **285,** 7-15, 1984 used numerical simulations to obtain the dynamical evolution of such globular cluster systems. They find about one-sixth of the initial number of globular clusters end up as inter-galactic clusters, and as such should be detectable in the Virgo Cluster, where about 100 globular clusters per square degree should be observed. The extended distribution of the globular cluster systems of galaxies such as M49 and M87 may have arisen from the swapping process. Other halo objects should also partake in this form of process.

The density and temperature of the gas in cluster of galaxies was investigated by G.C. Stewart and A.C. Fabian of the Cambridge Institute of Astronomy and C. Jones and W. Forman of the Harvard-Smithsonian Center for Astrophysics and reported in 'The prevalence of cooling flows in clusters of galaxies,' *Astrophysical Journal,* **285,** 1-6, 1984.

They used data obtained from the Einstein Observatory (R. Giaconni *et al, Astrophysical Journal,* **230,** 540, 1979) of X-ray brightness profiles of 36 cluster of galaxies. The corresponding mass inflow rates are between 2 and 400 solar masses a year, thus possibly providing a significant fraction of the mass of the central galaxies. The typical mass flow rate of intracluster gas considered by the authors leads to the creation of a substantial *central* galaxy by a cooling flow alone.

The Mystery of Bayer's *Uranometria* - Part 2

THE QUEST FOR NATHANIEL BLISS

By A.T. Lawton & L.J. Carter

This article is a sequel to 'The Mystery of Bayer's *Uranometria,*' which appeared in March *Spaceflight,* (pp.117-128). At that point the only firm reference was to Nathaniel Bliss, coupled with the knowledge that Bradley and Bliss were friends. It was necessary, therefore, to discover more about the enigmatic Bliss and to identify both his (and Bradley's) circle of friends and thus solve the question by reference to any records left by Bliss which might identify who the mystery observer might be. In addition, having established that our Bayer was a first edition, a further step would be to see who the probable *earlier* owner(s) might have been.

Introduction

At the conclusion of the previous article a number of unresolved points remained. Among these was the question of the publication of Bradley's results for the period 1747-9 for, if these were lacking, the result would be to substantiate the view that James Bradley was the author of the mysterious papers pasted into Bayer's *Uranometria.* The first course, therefore, was to seek more information about James Bradley.

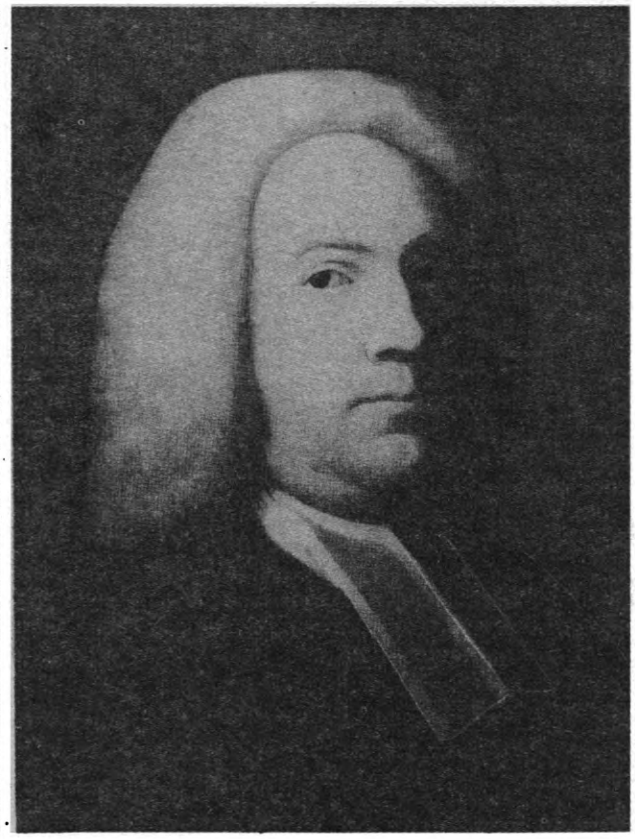
James Bradley

There is no doubt that James Bradley, the Third Astronomer Royal, was a brilliant man. He was a methodical, dogged and persistent worker, never content with measurements and observations that were less than the best his apparatus could yield. Tribute to these observations appears in many sources but perhaps the best two examples are from Jean Delambre (1749-1822) and from Richard van der Riet Woolley (1906-). Delambre was an observational astronomer who succeeded Lalande to the Chair of Astronomy at the College de France. His work included measuring a meridian arc between the parallels of Dunkirk and Barcelona which served as the basis of the (then) new metric system. In his *Histoire de l'Astronomie au 18 Siecle,* published after his death, Delambre wrote 'Bradley's observations raised him above the greatest astronomers of all times and countries' [1].

This may be an overstatement but Delambre was writing almost a century after Bradley had made one of his outstanding discoveries (the aberration of light) in the quest for stellar parallaxes and, even up to Delambre's time, no one had satisfactorily measured the parallax of even the nearest stars. Bradley had prophesied 'the parallax of the fixed stars is much smaller than hath been hitherto supposed... it does not amount to more than two seconds of arc.. if it were one second of an arc I should have perceived it.' [2].

Bradley's prophecy was all too true for, when finally measured with reasonable accuracy, the largest parallax was 0.75 secs of arc - but this was in 1836, 14 years after Delambre died, so at *his* time of writing the French astronomer was not exaggerating.

Woolley (the 11th Astronomer Royal) was much nearer the mark when he said that Bradley was 'the greatest astronomer who has ever held the office of Astronomer Royal in nearly three centuries' [3]. Woolley was speaking from the viewpoint of a practical astronomer, having himself contributed major papers on the formation of galaxies based on observations of the radial velocities of stars.



James Bradley, Third Astronomer Royal. *RGO*

Those 'Missing Years'

At that point the search for Bradley's missing observations undertook an astonishing about turn. This stemmed from a letter from Adam Perkins at the Royal Greenwich Observatory advising that he had discovered, to his own surprise, that the 'missing years' of Bradley's observations *had* indeed been published. They had been reduced by Hugh Breen and published by Professor Arthur Auwers at Leipzig in 1914, appearing in three volumes with the title of *Bearbeitung der Bradley'schen Beobachtungen.* The third volume comprised a catalogue of 4219 stars for the epoch 1745, based on observations made with the Transit instrument over the period 1743-1750 and of the quadrant over the period 1743-1753. (We subsequently discovered that Auwers had produced an even earlier paper *Neue Reduktion der Bradleyschen Beobachtungen aus den Jahren 1750 bis 1762* published in 1888 by the Academy of Sciences of St. Petersburg, Russia.)

Adam then went on to say that not only were the original texts of Breen's papers and Bradley's observations held at Herstmonceux but that he had compared some of them with those by the mystery author and found inconsistencies that made it unlikely that the latter had been prepared by Bradley.

With our main suspect apparently eliminated, our 'whodunnit' thus became a bigger mystery than ever. The only thing to do was to search for more clues.

More Hypotheses

One explanation could be that the writer of the enigmatic notes in the Bayer possessed by the Society was

III. DRACO.

Flamstead	Ptolemy	Tycho	Draco. The Dragon — Bayer's Names		Right Ascension ° ' "	Distance from the N Pole ° ' "	Longitude by the Signs S ° ' "	Long. from ye first of ♈ ° ' "	Latitude North ° ' "	Var. of R. Ascens. ' "	Var. Dist. N. P. ' "	Mag.
	31	31	Last of the Tail	λ	169 03 50	19 26 31	♌ 6 46 35	126 46 35	57 13 24	69 16	23 24	4
			Contiguous to it & Seq.		170 16 44	19 16 16	7 16 40	127 16 40	57 30 55	67 53	23 30	6
					184 44 41	19 29 53	3 20 40	123 20 40	61 10 10	50 07	23 51	6
	30	30	Last but one of the Tail	κ	185 36 10	18 48 51	12 39 28	132 39 28	61 43 40	48 51	23 49	4
5			Following this		185 59 43	18 34 35	12 32 45	132 32 45	61 57 45	48 16	23 48	5
	28	28	Præced. the Antepenultima	ι	206 02 26	24 01 03	♍ 1 18 49	151 18 49	65 21 50	31 30	21 33	5
	29	29	The Antepenultima of the Tail	α	209 25 03	24 24 10	3 50 41	153 50 41	66 21 43	29 07	20 54	3
	27	27	Præced in the last bending	ι	229 47 29	30 10 18	♎ 1 19 57	181 19 57	71 03 49	23 21	15 32	3
	26	26	Seq. in the same bending	θ	239 15 29	30 46 45	13 08 04	193 08 04	74 25 09	20 24	12 19	3
10	25	25	Præced of the 2 following in ye last bend.	η	245 09 09	27 54 31	10 25 04	190 25 04	78 27 62	13 54	10 07	3
		20	North in the third bending.	A	247 28 02	20 40 [illegible]	♏ 1 29 34	151 29 34	81 06 11	3 * 50	9 11	6
	22	20	Last of those following the last bending	g	249 51 38	24 55 53	♎ 0 36 30	180 36 30	81 39 25	6 31	8 16	6
			Middle in the third bending, double	b	253 42 30	24 20 15	0 58 28	180 58 28	83 19 35	4 25	6 44	6
				b	253 50 53	24 33 57	1 54 10	181 54 10	83 21 30	4 36	6 40	6
5	1	1	In the Tongue	μ	254 56 21	35 11 28	♏ 20 58 35	230 58 35	76 14 30	22 14	6 16	6
	24	24	Seq. in the third bending	ζ	257 05 11	22 58 04	♍ 29 23 23	179 23 23	84 47 29	2 26	5 21	3
	3	3	That above the Eye	β	261 04 50	37 29 43	♐ 8 08 07	248 08 07	75 18 35	24 13	3 50	3
	2	2	In the Mouth, double	ν	261 41 40	34 37 34	6 25 03	246 25 03	78 10 38	20 44	3 33	5 6
				ν	261 43 56	34 38 19	6 30 25	246 30 25	78 10 07	20 45	3 33	5 6
20	21		Præced the two seq. the 3d bending	f	263 31 52	21 39 49	♌ 21 12 03	141 12 03	86 52 52	4 * 54	2 13	6
	20	21	Seq. of them	ω	264 47 30	21 07 52	8 05 41	128 05 41	86 54 30	6 * 40	2 10	5
					265 39 22	39 08 29	♐ 19 53 44	259 53 44	74 11 06	25 44	1 33	6
	17	17	Præced. of the Præced Δ in ye Belly	ψ	267 11 04	17 43 51	♋ 9 57 59	99 57 59	84 07 35	19 * 44	1 17	4
	4	4	At the Jaw	ξ	267 17 01	33 04 19	♐ 21 08 43	261 08 43	80 19 43	18 20	1 14	4
25	5	5	Bright one in the Crown of ye Head	γ	267 39 45	38 27 53	24 23 05	264 23 05	74 38 26	24 57	1 07	2 3
			Another & Seq to ψ		270 25 30	17 58 60	♋ 0 12 54	90 12 54	84 19 50	18 * 38	0 05	5 6
					273 11 15	25 43 03	♒ 3 08 49	303 08 49	87 25 03	5 26	1 20	6
	6	6	North of the 3 of ye first bend of ye Neck	b	275 06 57	31 22 07	♑ 18 59 51	288 59 51	81 48 48	15 56	2 02	6
	18	19	South of ye Præced Δ in the Belly.	φ	276 30 34	18 52 25	♊ 07 33 40	67 33 40	84 50 02	14 * 37	2 38	4
30	19		North in the same Triangle	χ	276 57 52	17 27 12	12 49 30	72 49 30	83 30 27	20 * 40	2 47	4
	8	8	Middle in the first bending	d	277 06 19	33 12 45	♑ 22 25 32	292 25 32	79 47 27	18 43	2 51	6
	7	7	South in the same bending	c	279 28 18	34 58 01	26 18 55	296 18 55	77 44 16	21 13	3 49	6
	9	9	Seq. the first bending.	o	281 56 12	30 58 10	♒ 11 43 22	311 43 22	80 49 31	16 01	4 51	6
					283 10 42	32 39 12	10 13 27	310 13 27	79 06 28	18 34	5 21	6 7
35					283 41 21	16 26 53	♊ 4 17 25	64 17 25	81 35 55	24 * 08	5 32	5
					283 58 19	34 50 18	♒ 7 32 47	307 32 47	76 57 50	21 34	5 39	6
					284 51 03	37 07 55	5 39 33	305 39 33	74 40 03	24 13	6 00	5
	15	14	Præced. in the seq Δ of the Belly	υ	284 46 01	19 12 02	♉ 16 51 44	46 51 44	83 09 31	11 * 42	6 02	5
					286 46 14	33 43 52	♒ 16 18 22	316 18 22	77 13 18	20 35	6 47	5
40				a	287 14 50	32 53 40	19 36 18	319 36 18	77 44 31	19 35	7 03	6 7
	11	11	North in □ of ye second bend of ye Præc side		288 10 41	22 58 44	♈ 13 58 25	13 58 25	82 51 04	1 11	7 27	3
	10	10	South of the same side	π	289 53 24	24 58 35	0 14 16	0 14 16	81 18 28	6 30	8 06	4 5
					290 39 12	14 06 12	♊ 5 43 42	65 43 42	78 38 10	35 * 00	8 15	6
	16	15	North of the seq Δ in the Belly	τ	290 39 19	17 21 22	♉ 21 20 22	51 20 22	80 27 38	17 * 08	8 21	5
45	14	16	South of the same Triangle	σ	293 20 18	20 59 14	♈ 28 28 52	28 28 52	80 53 11	2 * 35	9 27	6
	12	13	North of the Seq. in □	ε	297 21 52	20 39 42	29 21 51	29 21 51	79 26 17	1 * 13	10 59	4
			Inform near ye Arm of Cepheus double	e	299 44 21	26 11 00	2 54 05	2 55 05	77 29 00	12 27	11 48	5 6
				e	299 55 11	26 22 54	2 15 04	2 15 04	77 19 45	12 52	11 53	7
	13	12	South of the Seq. in □	f	300 28 05	29 09 14	17 04 53	17 04 53	78 07 15	6 25	12 05	5

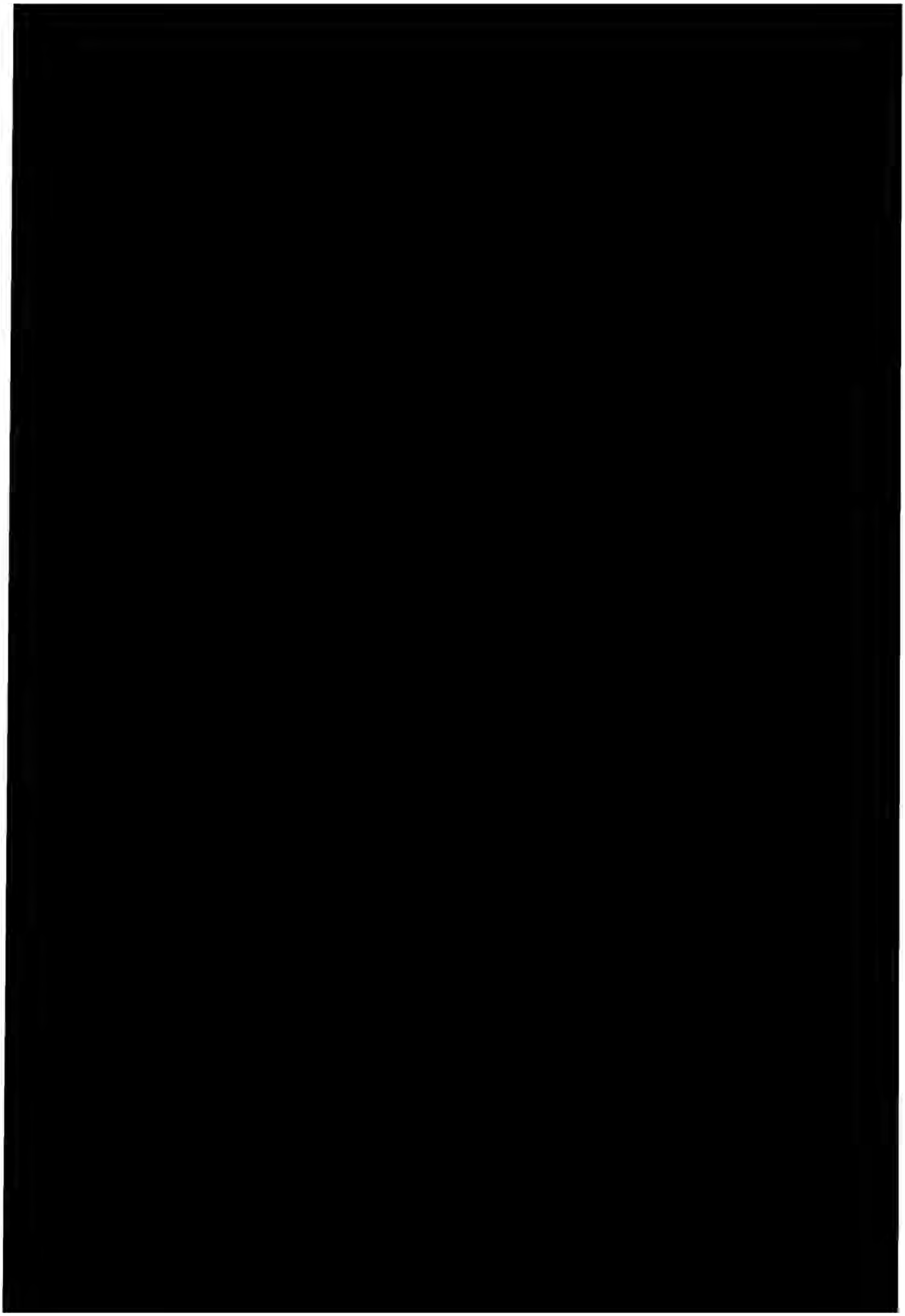
N B. Those Stars markt with the Asterisc * being situated between the Poles of the World & Ecliptic, seem to be carryed with a Retrograde Motion in respect of Right Ascension, from the Recess of the Æquinoctial Points, while all the rest move on in Consequentia according to the other above noted Variations.

K. The Pole of the World.
L. The Pole of the Ecliptic.
♑ ♋. Part of the Solstitial Colure.
M M. Part of the Equinoctial Colure.
N N. Part of the Artic Circle.
O O. A Parallel of the Ecliptic passing through the Pole of ye World.

7 Stars by the Pole of ye World. The LITTLE BEAR.
17 from ♈ to ♊. In the Constellation CEPHEUS.
13 from ♒ to ♈. In CYGNUS.
14 from ♏ to ♑. HERCULES ENGONENSIS.

Facing page: the page of observations for Draco (Map III) in Latin; *above:* the subsequent additional page corrected to the later epoch.

someone who knew Bradley extremely well, but was not completely in the mainstream of developments in astronomy - particularly in the publishing field. Bradley himself would have been aware, or would have been made aware by Nathaniel Bliss, of the intentions of Dr. Bevis and Mr. Neale to publish a set of plates after the fashion of Bayer but with explanatory texts both in Latin and English. Indeed, our copy of Bayer's map contains a handwritten note stating that the owner actually had been advised of this development by Bliss. Could, therefore, information about the correspondents of Bliss lead us back to the mystery writer, particularly since, from the information gleaned about Bradley, it seemed out of character for Bradley to have prepared 11 plates and then stopped? Either he would have finished the work or would have been so busy that he could not have started it.



Another approach concerned the Bayer atlas itself. Having once established that it was a first edition, a logical step was to deduce who its first owner(s) might have been, bearing in mind that 144 years elapsed between the initial publication of the Bayer in 1603 and the updating by its mystery observer.

If Bradley was involved, then the previous immediate owner might have been his uncle, James Pound or even Samuel Molyneaux. This was suggested by Latin words written on the title page of our *Uranometria* reading 'Vide clausus puriter libraris - Epo 27 et ult,' which may be translated as 'Seen more clearly in the enclosure for Epoch 27 (i.e. 1727) and beyond.' In other words, this implied that these observations had been put into the Bayer from 1727 onwards and not 1747, as the long handwritten sheet had indicated.

This short text is in 'Grave Latin,' for it uses the shorthand phrases found on gravestones. Who but a clergyman would do that? Additionally, the pages are numbered in unusual format e.g. VIIII for '9' instead of the academic IX. It is likely that Pound, if the first owner, would have done something like this though the date chosen, Epoch 1727, was actually shortly after his death.

The next step, therefore, was to learn both about James Pound and, for good measure, about in his immediate circle of influential friends.

James Pound (1669-1724)

It soon emerged from our enquiries that, although brilliant by nature, Bradley was greatly assisted in his career by relatives and friends who were also eminent men of their times and in one or two cases so outstanding that they are giants of history. Included here are Isaac Newton and Edmond Halley, both friends and contemporaries of Bradley and also of his astronomer uncle James Pound. Sir Isaac, undoubtedly, visited Pound at Wanstead on more than one occasion. Not only did he give money to Pound to help him with his work but also arranged for the imposing Maypole in the Strand to be taken down and sent to Dr. Pound as a present - to be set up to support his telescope, 125 ft long and the largest in Europe. The move caused so much comment that the enlarged edition of Stow's Survey of London, 1720, by the Rev. John Strype, Vicar of Low Leyton, tells us that it had not long been set up in Wanstead before the following verses were fastened upon it by an unknown hand:

Once I adorned the Strand,
But now have found
My way to POUND,
In Baron Newton's Land.

Where my aspiring head aloft is reared,
T'observe the Motions of the Ethereal Herd,
Here sometimes raised a Machine by my side,
Thro's which is seen the sparkling Milky Tide;
Here oft I'm scented with a balmy Dew,
A pleasing Blessing which the Strand ne'er knew.
There stood I only to receive abuse,
But here converted to a nobler use;
So that with me all Passengers will say
I'm better far than when the Pole of May.

The Maypole seems to have been broken up in 1728.

Pound, although an amateur astronomer, was a professional clergyman and for the major part of his clerical life, from 1707 to 1724, had the living of the Parish of Wanstead (James Bradley was a former curate of the Parish Church there) in Essex under the patronage of Sir Richard Child, First Baron Newton and Viscount Castlemaine who subsequently became the first Earl of Tylney.

Title page of the Society's *Uranometria* with the 'Grave Latin' inscription arrowed.

This very early acquaintance with the patronage of peers was to be a valuable aid to young Bradley and stood him in good stead in his later years when he was constantly in contact with powerful and influential men and had attained the highest position in his profession: that of Astronomer Royal. James Bradley, third son of William and Jane Bradley (née Pound), had been born at Sherborne, Gloucestershire about 1692, was educated at North Leach Grammar School and then entered Balliol College, Oxford, on 15 March 1711 in his 18th year. He became a B.A. in 1714 and M.A. in 1717. He contracted smallpox shortly afterwards and was cared for by Dr. Pound.

About four years later, when Dr. John Kiell (the incumbent Savilian Professor of Astronomy at Oxford) died, several candidates were considered as his successor, among them the Rev. James Pound. It will be remembered that Pound was an *amateur* astronomer who took his patronaged living as a *professional* clergyman. Now he was being urged to switch roles i.e. to become a professionally paid astronomer at Oxford and give up his beloved Wanstead Rectory, at that time a haven of peace and quiet out in the country and with very dark skies.

It was too much for Pound. In spite of being sponsored by the most powerful man in England, Lord Chancellor Parker, the First Earl of Macclesfield, Pound decided to opt for the clerical life. It was understandable for he was then 52 and, had he known it, had just three more years to live. Pound therefore appealed to Lord Parker to sponsor his nephew, James Bradley. His appeal was supported by Martin Foulkes (later to become President of the Royal Society) who wrote to Archbishop Wake in a letter dated 4 September 1721 that 'he (Bradley) has

NATHANIEL BLISS.
(From an engraving on an old pewter flagon.)

lived for some years with his uncle Mr. Pound of Wanstead, where he has had great opportunities of joining to his theory the practical part of astronomy, in which he has made himself very eminent... I shall only take the liberty of adding that he is perfectly approved and will be entirely recommended by Sir Isaac Newton, whom your Grace knows for the great judge of this sort of learning' [4].

Edmond Halley who, by then, was the second Astronomer Royal would also have approved of the appointment. In fact, Halley thought so highly of Bradley that in 1739 he offered to resign his position of Astronomer Royal in Bradley's favour. In the event Bradley was appointed to this honoured position by Sir Robert Walpole on 3 February 1742 and retained it to his death in July 1762.

Meanwhile, Lord Parker, who had considered Pound to be 'the fittest man perhaps in Europe' [5] for the professorship now sponsored James Bradley who, at the age of 29, thus relinquished his clerical living to become a professional astronomer. He was duly elected Savilian Professor on 31 October 1721, admitted to office 18 December 1721, and read his first lecture 26 April 1722.

Nathaniel Bliss

High in this circle of friends was Nathaniel Bliss, referred to in the atlas as having corresponded with the mystery observer. If, therefore, documentation still existed regarding Bliss and his circle of contemporaries, a list of all possible owners of the mystery Bayer might be compiled. Nathaniel Bliss and James Bradley were long-standing friends who had been in regular correspondence for 20 years. Over this time Bliss had, on some occasions, assisted Bradley with his observations at Greenwich.

Bliss graduated from Pembroke College, Oxford, taking his BA in 1720 and MA in 1723. He always had considerable mathematical abilities but his early career was also in the Church, for he became Rector of an Oxford parish in 1736. On Halley's death in 1742 he was appointed Savilian Professor of Geometry and became a Fellow of the Royal Society. He then opened correspondence with James Bradley, one of the first matters being about observations of the Jovian satellites.

Both Bliss and Bradley were also friends and correspondents of George Parker, the 2nd Earl of Macclesfield. It was Bliss who had requested the Earl, on 12 February 1744, to make a meridian observation of the comet then approaching the Sun. This was successfully done on 28 and 29 February, both at Shirburn Castle (the Earl's country seat) and at Greenwich.

Bradley was in such poor health at the time of the June 1761 transit of Venus that he was unable to make any major contribution, so the vital Greenwich observation of this event were made by Bliss. (Some of Bradley's written instructions for the phenomena are still preserved.)

With the personal knowledge that he had gained working with Bradley at Greenwich, Bliss was the natural successor to the post of Astronomer Royal, and was appointed soon after Bradley's demise in July 1762. Unfortunately, Bliss remained in office only two years as he himself died on 2 September 1764, thus making only a slight impression on the history of the Royal Observatory.

It was during the period of Bliss's tenure, however, that Nevil Maskelyne and John Harrison took part in the second historic trial of Harrison's marine chronometer number 4 on a voyage to Barbados in the West Indies. Maskelyne returned from the voyage to become the fifth Astronomer Royal, after Bliss's untimely death.

Bradley's assistant in the final years of his life had been Charles Green, who continued in this post under Bliss. The observations made under supervision by Charles Green were subsequently regarded as the Astronomer Royal's private property, so they were purchased from his widow by the Board of Longitude and deposited at the Royal Observatory until 2 March 1804, when they were offered to the Clarendon Press for publication. They were appended, along with those made by Green after Bliss' death, down to 15 March 1765, to the second folio volume of Bradley's observations, issued under Professor Abram Roberton's editorship in 1805. Although including only what was indispensable in order to deduce the places of the Sun, Moon and planets at the most important points of their orbits (see Delambre, *Hist, de l'Astr au 18th Siecle,* p.425), they are valuable as being made on Bradley's system and with Bradley's instruments.

Bliss married early and a son, John, born in 1724, proceeded to a BA at Oxford on 11 March 1745-6 and his MA on 7 July 1747.

The Earls of Macclesfield

The fact that both Bradley and Bliss had a personal friend in George Parker, the second Earl of Macclesfield, provided a valuable further clue, particularly as the Earl had been a keen astronomer, an accomplished observer and possessed fine astronomical instruments. It appears established that the acquaintance between James Bradley and the Parker family lasted for much of the First Earl's

BAYER FACSIMILE

The Society's Bayer facsimile will appear as a limited edition of 500 copies only. Two versions will be available, one bound in Buckram (£160) and the other in calf vellum (£250). They will be identical in all respects except for the binding. Members interested in securing copies (there will probably be a special pre-publication price) are asked to make their wishes known to the Executive Secretary at HQ as soon as possible.

George, Earl of Macclesfield, painting by T. Hudson. *Royal Society*

life, and for most of the life of the Second Earl - and certainly for the rest of Bradley's life, as witness the fact that Bradley published his results on nutation in a famous letter to Lord Macclesfield in early 1748.

It appeared that the Earldom was created in 1721 and that the second Earl was Lord-Lieutenant of Oxfordshire i.e. where both Bliss and Bradley had been Savilian professors. This could prove very significant, for it would have provided the Earl with access to paper bearing a Royal watermark, as was used by our mystery observer when recording his observations in our copy of Bayer's *Uranometria*. It also provided a suitable candidate who, although outside the mainstream astronomy of Bradley, Bliss, Green, and Maskelyne, was nevertheless a keen astronomical observer in correspondence with these men.

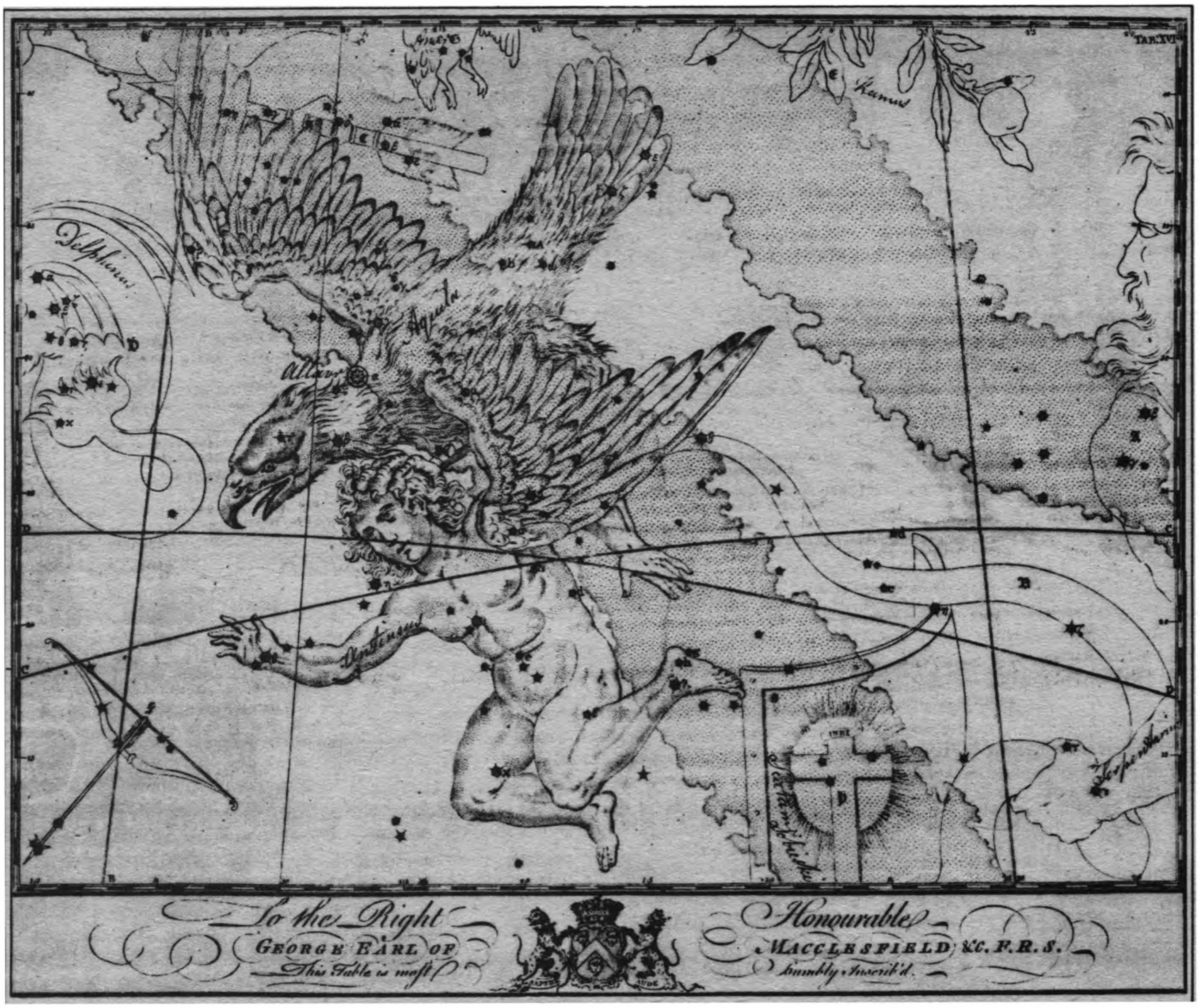
The next step was to establish the part of both the first and second Earls more closely, particularly since some of the observations made by James Bradley had actually been made at Shirburn Castle, the family home of both Earls. A description of the circumstances of the creation of the Earldom of Macclesfield appear in *Burkes Peerage and Knighthoods* and *Debretts Illustrated Peerage* which, condensed, shows that:

The Thomas Parker who became the First Earl of Macclesfield was initially an eminent lawyer in the reign of Queen Anne. He was the grandson of George Parker of Park Hall Stafford, (Sir George Parker, Bart., of Shenstone) and Grace - his wife - daughter of Hugh Bateman of Hartington in Derby, and the first son of Thomas Parker (elder) who married Anne, daughter and co-heir of Robert Venables of Nuneham, County Chester.

The young Thomas Parker was nominated one of Her Majesty's Council and, being called to the Office of Serjeant-at-Law, was appointed Queen's Serjeant and received the honour of Knighthood on 8 June 1705.

Sir Thomas was then elevated to the Chief Justiceship of the Court of the Queen's Bench in 1710 and to the Peerage by George I on 10 March 1716 as Lord Parker, Baron of Macclesfield, County Chester. His Lordship was constituted Lord High Chancellor of Great Britain on 12 May 1718, and Viscount Parker of Ewelme, Co. Oxford, and Earl of Macclesfield 15 November 1721.

The First Earl was born 23 July 1666 and married Janet, daughter and co heir of Charles Carrier of Wirksworth, Co. Derby on 23 April 1691. Their child was George Parker who became the 2nd Earl of Macclesfield: Deputy Lieutenant of the County of Oxford, Member of Parliament



A Bevis plate, dedicated to the Earl of Macclesfield.

for Wallingford 1723-1727 and President of the Royal Society 1752-1764.

In 1725 the First Earl was impeached on charges of corruption and, being convicted at the Bar of the House of Lords was, after a trial of 21 days, found guilty and sentenced to a fine of £30,000. This was an enormous sum for those days: at today's prices it would be between £3 to £4 million.

Surviving this blow to the family fortunes, the First Earl died in 1732 thus, for Bradley, ending a long friendship and marking another in a series of deaths of his friends in quick succession, for his uncle James Pound had died in 1724, Sir Isaac Newton in 1727 and his co-observer at Kew, Samuel Molyneaux, in 1728.

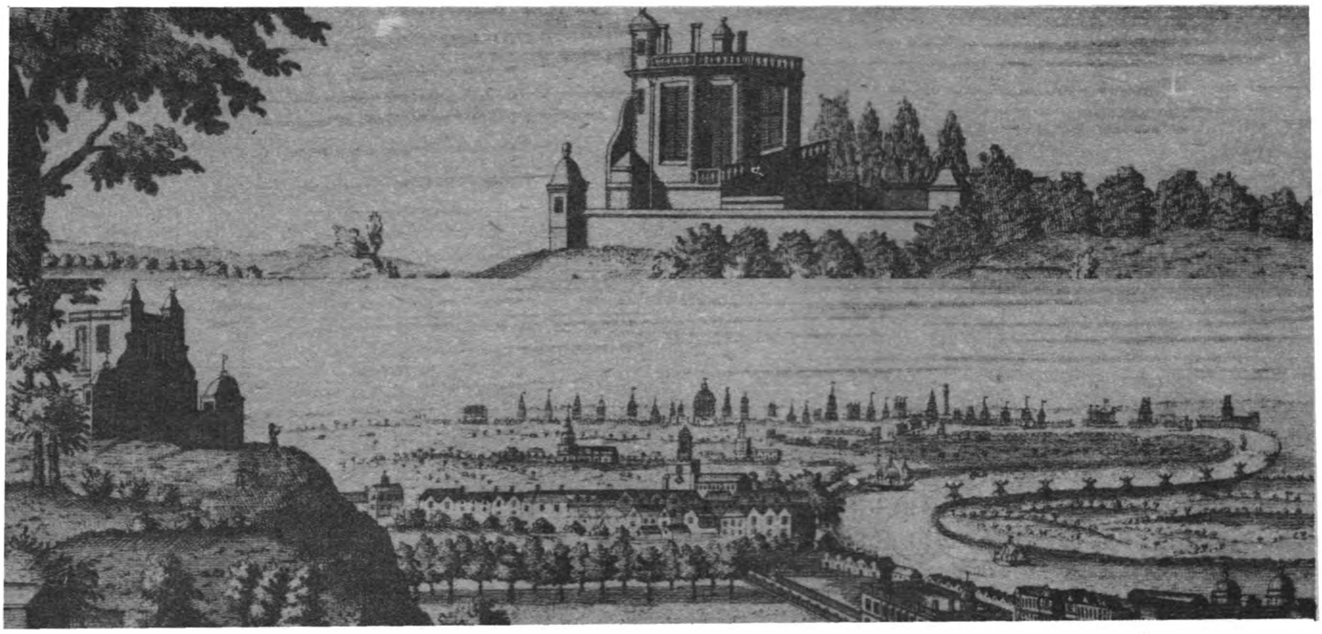
The deaths of four of his closest friends in only eight years could, it might be argued, have affected some of the emphasis of Bradley's life and work. After his Uncle's death he still worked at Wanstead, but no longer at the Rectory.

His ever-faithful Aunt Pound moved to a smaller house, 'The Grove' on her brother's adjoining estate at Wanstead. On 17 August 1727, Bradley built a zenith sector of 12½ ft (3.8 m) radius on the upper part of this house. This was superior to the instruments at Greenwich which had nothing to match it until Bradley moved there in July 1749. The height of the lower storey of the house was only 6½ ft (2.3 m)! This has a bearing on our Bayer's additional sheets for if these were compiled from Epoch 1727 onwards, this period (1727-1747) would fit in with a series of private observations made before moving to Greenwich in 1749. Indeed our Bayer and its observations and enclosures were firmly stuck together with a material believed to be jam. If jam was stored in the upper room of this tiny house the accidental spillage could have occurred in the 1749 move.

When Bradley and his Aunt moved to Oxford in 1732 - a move that almost certainly helped in the furtherance of Bradley's already existing friendship with Edmond Halley at Greenwich and with Nathaniel Bliss - he left this zenith sector at the Wanstead site, making frequent visits to 'The Grove' to continue observations until 1747, but then discontinued work with this instrument until it was moved to Greenwich in 1749. This two-year hiatus could be significant for most of the observations noted in the Society's Bayer Atlas relate to this time and might have been made with this instrument at Wanstead. Later work at Greenwich was published by Maskelyne after Bradley died. These were unreduced tables of raw observations by Bradley. The error-corrected reduced data tables for 1750-1762 were published by Auwers in 1888 [6] and 1914 [7].

George Parker, to be the 2nd Earl (1697-1764)

The move back to Oxford also helped to initiate and consolidate other friendships, particularly the long associ-



Views of the Royal Greenwich Observatory before 1750. RGO

ation with the Parker family. The first Earl had died in the same year that Bradley moved to Oxford but his son, the second Earl, had already struck a firm friendship with Bradley, the Savilian Professor of Astronomy.

George Parker, who was to become the 2nd Earl of Macclesfield, was elected a Fellow of the Royal Society in 1722, when only 25, and succeeded to the Earldom 10 years later. He pursued his studies at his country home, aided by Bradley and about 1739, erected an astronomical observatory containing equipment which was then perhaps the finest in existence. It contained a 5 ft transit and a quadrant (both by Sisson), clocks by Tompion and Graham, a 14 ft refractor fitted with a micrometer and later, a 3½ ft achromatic by Dolland. The Earl obtained from the Royal Society, in 1748, the loan of two object glasses by Huygens (one of these Huygens glasses had already been used by Bradley between 1718 and 1728), of 120 and 210 ft focus and had one, or both, mounted at Shirburn Castle. In 1742 he succeeded in procuring for James Bradley, his frequent guest and occasional assistant, the post of Astronomer Royal.

He began his series of astronomical observations in June 1740 and continued these almost to his death.

The Earl became famous subsequently for quite another reason, insofar as he played a prime part, in 1751, in putting through a Parliamentary Bill for regulating the commencement of the year. The bill included two major reforms:

1. Bringing the UK and the Dominions into line with most of Continental Europe in introducing the Gregorian calendar, replacing the Julian calendar which differed by 11 days.
2. Regularising the commencement of the year as 1st January and resolving the confusion over 'Lady Day.' Before Lord Macclefield's reform the time between 1 January and Lady Day was usually referred to by two dates.

At that time Lord Chesterfield had described him as 'one of the greatest mathemeticians and astronomers in Europe.' He was elected President of the Royal Society in 1752, a post he held for 12 years. Sadly, the Earl's involvement in correcting the calendar proved highly unpopular with the public for, when his eldest son contested the Oxfordshire Parliamentary seat in 1754, one of the cries from the mob was 'give us back the 11 days we have been robbed of.'

A Working Hypothesis

A tenable theory at this stage is that the Society has in its possession an original 1603 Bayer Atlas, possibly one that was acquired by James Pound who gave it *via* James Bradley to George Parker, the second Earl of Macclesfield, who had the worthy idea of correcting the plates but did not proceed with publication as a result of the labours by Dr. Bevis and Mr. Neale although gladly completing his observations and lists for his own private pleasure. The passage, in our *Uranometria,* supports the view that the person concerned had both the time and the private means to accomplish such a task. In the event, Bevis and Neale did not complete their project. A number of plates were made and prints taken from them - one of which was actually dedicated to George, Earl of Macclesfield - but these unfortunate men went bankrupt and their creditors seized the plates. No complete catalogues exist of the Bevis/Neale prints. It is believed that only 12 collections of their star maps now exist.

Thus, if our mystery writer *was* George Parker, second Earl of Macclesfield, both Bradley and Bliss would have had a hand in preparing the main body of figures associated with the Bayer plates. Nonetheless, we are still prepared for more surprises.

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3. R. van der Riet Woolley *Quarterly Journal of the Royal Astronomical Society,* **4,** (1963) p.52.
4. Extracted from *Wansted through the Ages,* by W.V. Phillips, Vawser and Wiles 1949, pp.79-84.
5. *Ibid.*
6. Auwers, G.F.A., *Neue Reduktion der Bradley'schen Beobachtungen aus den Jahren 1750 bis 1762.*

The third instalment on the story of the search for the identity of the Bayer's owner will consider other 18th century astronomers.

RESEARCH IN MICROGRAVITY

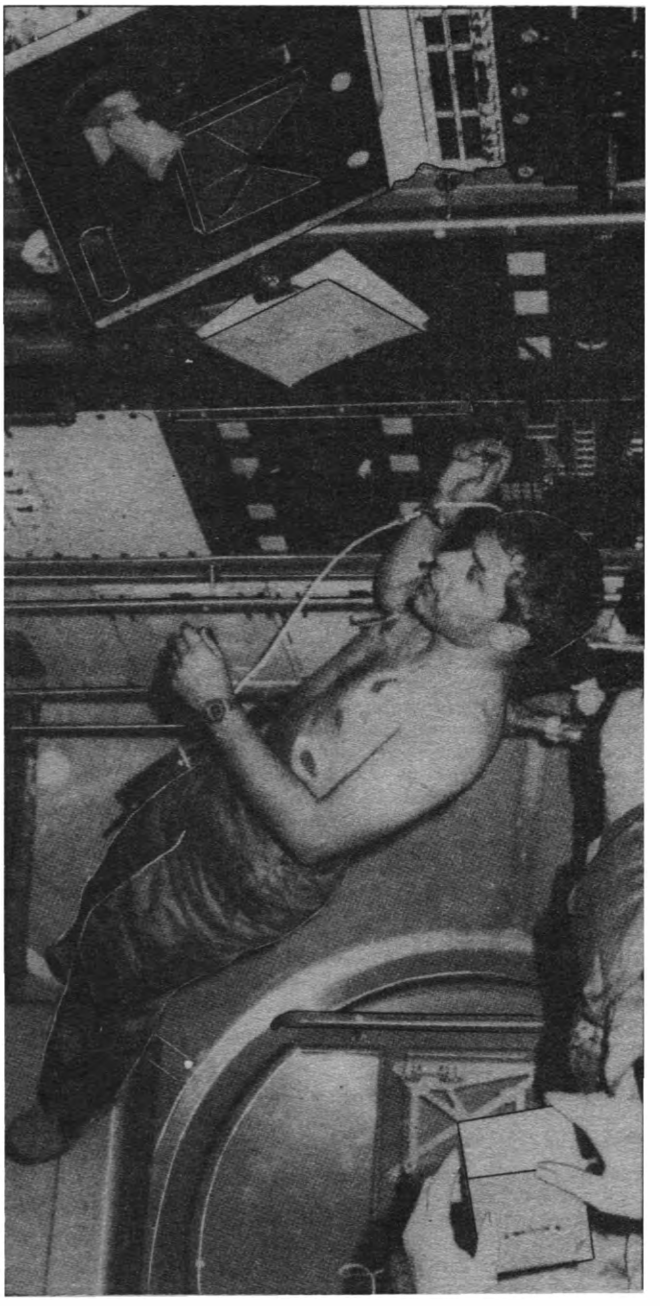
Technological progress, especially in high technology areas, is intimately linked to progress made with materials. Without proper materials, many of the technical systems we now take for granted would have been abandoned at an early stage. Some examples would be the mechanical structures for aeroplanes and spacecraft, semiconductor single crystals for solid state electronics, essential components for lasers, glass fibres for optical communication systems, single crystals for sensing infrared radiation and glasses for optical systems. As engineering becomes even more sophisticated, the requirements for materials specifically adapted and tailored to some particular application become increasingly stringent. Advances in understanding the fundamental properties of materials and the discovery of new phenomena often bring about even more advanced systems, since the development of advanced or even novel materials almost always spurs technological progress.

The realisation of reliable, high temperature nuclear reactors does not depend on conceptual techniques but on suitable materials. Computers operating at much higher speeds and having extended ranges of operating temperatures and much higher radiation hardness than systems based on silicon are now under development. These use Gallium Arsenide single-crystal chips but the desired quality is difficult to attain. Again, the operating temperature of a combustion engine is one of the keys to fuel efficiency and performance. To sustain higher temperatures and prolong lifetime, directionally solidified, or even single crystalline turbine blades, are being increasingly employed in jet engines instead of the standard casts of superalloys. In the US, Japan and Europe, considerable efforts are under way to develop ceramic materials for small gas turbines for automobiles. However, even with major problems related to reproducibility and reliability, the resulting demand for all types of advanced materials is almost limitless.

Even today, the development of materials is being pursued on the basis of empiricism rather than through the understanding of fundamentals. Often one refers to crystal growth as an 'art.' One reason for this is that the number of applicable materials is virtually endless; another is due to gravity. When the major component is a fluid, gravity causes convective flow whenever density gradients are present. This causes separation of components into heterogeneous mixtures whenever the densities are not equal and produces hydrostatic pressure gradients. In fact, heat treatment of liquids and solidification simply cannot be done without having thermal and density gradients. Gravity also makes the use of crucibles and containers mandatory on Earth.

A crucible that does not contaminate the 'melt' is not available for silicon, the key material used in solid state electronics. If high resistivity single crystals are required, one has to resort to techniques in which the melt is supported by unmelted material (float zone technique). It is practically impossible to conduct solidification experiments because of heat and mass transfer caused by convection. Sedimentation and buoyancy are also problems.

Fluid physics govern all processes involving liquids and gases. The study of fluids under both static and dynamic conditions is of fundamental importance in Material Sciences. Fluid statics is concerned with the behaviour of containerless fluids and of fluids in contact with solids.



Astronaut Bob Parker works on the Materials Science Rack during the flight of Spacelab 1 on 8 December 1983. *NASA*

Under microgravity conditions interfacial and surface tension are the dominant forces. The equilibrium shape of liquids in contact with solids and of immiscible liquids will be completely different in a microgravity environment. For complex geometries, such as encountered in fuel tanks or when processing materials from the molten state, this shape is difficult to compute or to simulate.

The study of fluids in motion comes under the domain of Fluid Dynamics. A microgravity environment offers a multitude of conditions. Simulation of microgravity by experimenting in a second liquid of similar density is only of limited value for the study of dynamic procedures since both inertia and viscous forces of the surrounding medium have to be taken into account. The dynamics of oscillations of freely floating and acoustically levitated drops are being investigated in the US and European Space Programme.

Life Sciences investigations are another important facet of Microgravity research but the association with living systems tends to draw an important dividing line between this and the Materials Sciences.

SATELLITE DIGEST -184

Robert D. Christy
Continued from the May issue

A monthly listing of satellite and spacecraft launches compiled from open sources.

The heading to each launch gives the name of the satellites, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

1985-14A, 15546

Launched: 0615, 8 Feb 1985 from Vandenberg AFB by Titan 3B.
Spacecraft data: Not available.
Mission: Military reconnaissance.
Orbit: Near-polar, low, Sun-synchronous.

ARABSAT 1 1985-15A, 15560

Launched: 2322*, 8 Feb 1985 from Kourou by Ariane 3 (V12).
Spacecraft data: Standard design vehicle built by Aerospatiale of France. Box-shaped body, 2.26 x 1.64 x 1.49 m, with a two panel solar array of width 20.7 m. The design of Arabsat permits use of Shuttle as an alternative launch vehicle. Attitude control is performed by momentum wheels and station keeping is by a bi-propellant rocket engine. The mass at launch was 1195 kg, reducing to 592 kg after the apogee boost motor firing and depletion of orbit correction fuel.
Mission: Communications satellite covering Arab-speaking countries in North Africa and the Middle East. The payload consists of 25 C-band transponder channels, and a single TV transponder providing signals to small, community aerials.
Orbit: Geosynchronous above 19°E longitude

BRASILSAT 1 1985-15B, 15561

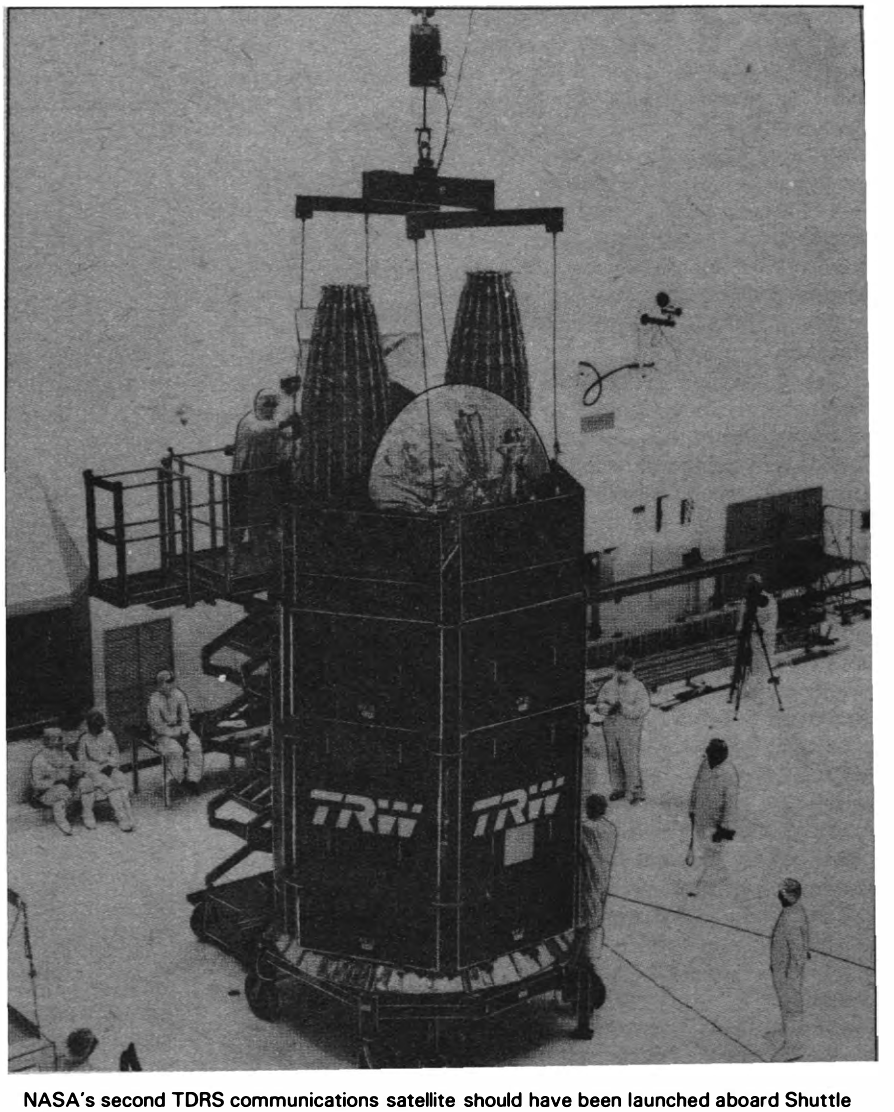
Launched: 2322*, 8 Feb 1985 from Kourou by Ariane 3 (V12).
Spacecraft data: Cylindrical, spin stabilised vehicle with a de-spun aerial array at one end. Diameter is 2.16 m and the length 2.95 m at launch, extending to 7.04 m in orbit. The launch mass was 1140 kg, reducing to 671 kg after apogee kick motor firing.
Mission: Brazilian national communications satellite providing 24 C-band channels (6 GHz uplink, and 4 GHz downlink). The design life is 8-10 years.
Orbit: Geosynchronous above 65°W longitude.

COSMOS 1629 1985-16A, 15574

Launched: 0757, 21 Feb 1985 from Tyuratam by D-1-E.
Spacecraft data: Not available, but may be similar to the Gorizont/Raduga satellites.
Mission: Possibly developmental, experimental or military communications satellite.
Orbit: Geosynchronous above 88°E longitude.

COSMOS 1630 1985-17A, 15582

Launched: 1110, 27 Feb 1985 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and cylindrical supplementary package at one end. Length about 6 m, diameter (max) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaissance.
Orbit: 174 x 334 km, 89.60 min, 64.89° manoeuvrable.



NASA's second TDRS communications satellite should have been launched aboard Shuttle 51E during March but the mission was cancelled when it was discovered from TDRS-1, in orbit since April 1983, that outside interferance could affect the communications links. Since TDRS also carries military traffic, modifications are underway. *NASA*

COSMOS 1631 1985-18A, 15584

Launched: 1258, 27 Feb 1985 from Plesetsk by C-1.
Spacecraft data: Not available.
Mission: Military, possibly radar calibration or electronic reconnaissance.
Orbit: 472 x 512 km, 94.46 min, 65.87°.

COSMOS 1632 1985-19A, 15589

Launched: 1040, 1 Mar 1985 from Plesetsk by A-2.
Spacecraft data: As Cosmos 1630.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 211 x 268 km, 89.30 min, 72.88°.

COSMOS 1633 1985-20A, 15592

Launched: 1540, 5 March 1985 from Plesetsk, by F vehicle.
Spacecraft data: Probably a cylinder with two, Sun-seeking solar panels. Length about 5 m, diameter 1.5 m and mass around 2200 kg.
Mission: Electronic reconnaissance.
Orbit: 634 x 660 km, 97.72 m, 82.56°.

FROM THE SECRETARY'S DESK

2010: Odyssey Two

Dr. L.R. Shepherd, Chairman of the Society's International Liaison Committee, and myself were among an audience of some 1300 attending the Royal Charity Premiere in London on 4 March of the film version of Arthur Clarke's *2010: Odyssey Two* in the gracious presence of their Royal Highnesses the Prince and Princess of Wales. The guests, who had arrived in good time suitably attired in black ties and dinner jackets to await the arrival of their Royal Highnesses, were entertained in the interval with a selection of music by the Band of the Coldstream Guards.

The film itself was a highly-polished professional affair, notable for an astonishing variety of special effects. The story-line was crystal clear, unlike *2001 - A Space Odyssey* which, although it brought a new era of sophistication to science fiction films, was so obscure that the book *had* to be read beforehand if the film was to be fully understood. Not intending to be caught out twice, I read the book first of all but, in the event, the only changes I noted were the omission of any reference to the Chinese expedition and the sequence where it was destroyed by a life-form on Europa.

The mysterious monolith once more rivetted attention. I realised how Ulysses' seamen must have felt, staring at its predecessor, the mysterious Pandora's box. What *was* it? The author, cryptically, described it in a subsequent television interview as a sort of Swiss Army knife.

I chuckled to see Arthur, himself, in the film. He first appears as a non-speaking tramp-type character sitting on a bench before the White House, feeding pigeons. This provided a mental comparison with a description of his arrival in Los Angeles for the promotion of *2010* last year when *The Atlanta Constitution* of 26 December 1984 described him as 'looking more like a retiring banker.' His second appearance is as a 'prop' in the form of one of two faces on the front cover of an issue of *Time* magazine. The second visage, incidentally, is that of Stanley Kubrick, the director of *2001*.

Arthur Clarke is presented to HRH The Prince of Wales.

Quick Getaway

I was one of those at the Press Reception at the Science Museum on 4 March to hear the results of the ITN Getaway Special schools competition.

The BIS was particularly well represented. Introducing the winners, A.C. Clarke, replete in BIS tie and badge. paid a graceful acknowledgement to the Science Museum for risking their reputation on space matters once before, for several 1937 BIS meetings were held there. In fact, the Science Museum saw a demonstration of our one and only experimental device, the coelostat, designed to provide a stationary view from a rotating spaceship, adding the information that its rotating base had actually been part of his old gramophone.

The first prize was awarded to Ashford School for Girls. Runner-up was Matthew Humberstone Comprehensive School (Cleethorpes). Last year Space Consultants International had bought its own Getaway Special and now offered this to the runner-up with the result that two school experiments will now fly, probably, next year.

Peter Conchie, a former Member of the Society's Council, added how very difficult it had been to choose between such excellent projects adding that, as consolation prizes, all entrants would receive models of the Shuttle.

Value for Money

Most members simply relate their dues to the value of the magazines they receive: few consider that part of a subscription can actually be wasted by late renewal of annual subscriptions.

Every member, on election, signs an undertaking that he (or she) will remit dues on or before 1 January each year. A very large number do so, with those who have completed direct debit forms relieving us of a considerable burden. On the other hand, a substantial number (a thousand or more) are very tardy and hold back payment until after receiving a number of special reminders. This is where the waste comes in. Handling and re-handling members' records, preparing envelopes, setting up and printing off reminders and all the problems of assembly and dispatch do not come free. There is a high overall cost in time and effort which we would clearly love to utilise more effectively elsewhere.

Collecting subscriptions from tardy members costs between £2-5 per time, which makes it quite a sizeable chunk out of their annual dues and which they tend to disregard.

Nowadays, nearly everyone has a bank account so completing a direct debit - such a simple step - reduces all these problems.

First Day Covers

Our collection of first-day covers on astronomy and space is now approaching 1,300 items, having been augmented recently by two very useful batches. Our aim, when our Library extension takes place, is to prepare displays on particular events, changing these as necessary to provide continuing interest.

Starting the collection was a tricky task. We had a few FDC's but little idea where the rest would come from. Fortunately, several members and others interested got us off to a good start with contributions ranging from

Collecting First Day Covers is an excellent - and sometimes quite inexpensive - way of building up a collection of space history.

ones and twos to tens and, once or twice, hundreds! Sometimes I think we have done well but come close to despair at others to see lists of covers, running into thousands, which we don't have.

Our collection falls into several groups. Those to do with pre-war rocket experiments are rather thin on the ground, those relating to astronomy even thinner. We are back-tracking to get extra early space covers on projects Mercury, Gemini and Apollo though there is still some way to go. We also find it hard to keep up with the output of current covers. It would be easy to buy these from a Philatelic Agent and get them regularly but there are too many other demands on our funds, hence our need to ask members to help whenever they can.

Particular thanks are due to Keith Wright who keeps an eye on ESA covers for us, to Rex Hall who does the same for Soviet covers, to Les Winick for ever-helpful advice and to the very many individuals who also wade in from time to time.

Not All for One

In any group there is always someone who will not conform. It happens in our Society as well so, when it does, I need to point out that our work is for the benefit of *all* – not just a few, still less for some individual gain.

Our Constitution makes this plain. For example, Bye-Laws prohibit using Society functions for the free display and distribution of literature or similar materials – even surreptitiously – without prior permission. Even so, sad to say, some still try to use the Society for their own purposes.

A member who transgresses is reminded his written undertaking to observe the Society's Constitution. Others, especially if promoting commercial interests, are warned to behave, or depart.

Vandal-time

Last January our local Mail Sorting Office was broken into and a good deal of mail damaged or destroyed, including about a hundred items meant for the Society. Torn letters, odd cheque slips without remittances and similar items arrived piece-meal over many weeks. We have tried to sort out the chaos but in case items were destroyed completely, please write again if you are still without a reply.

Out of the Frying Pan

Contemplation of Deane Davis setting his trousers alight while giving a lecture led to an interesting train of thought, beginning with the recollection that I once followed the American Ambassador in being invited as Guest of Honour to present prizes at a very large school, the Ambassador having done the chores first time round and myself as the not-quite-made-it Celebrity following on.

I remember both congratulating and presenting shoals of children with attainment certificates in Greek. It was only later that I discovered that that was their native tongue.

Another pearl of wisdom for would-be speakers is *never follow animals*. I never give a talk to any group if their previous speaker had access to a zoo and showed off animals. These speakers always produced lots of cuddly bears, snakes, and the like. Everyone crowded round and had a whale of a time.

The following speaker appears a dull, drab, and uninteresting fellow by comparison.

Take my tip, *never* follow animals.

Free for All

The Editor is always interested in receiving items of correspondence, notes, comments, or reviews for possible publication. Items submitted need to be kept brief, owing to the limitations of space in our magazine. For the same reason the Editor reserves the right to shorten or otherwise adapt material to fit.

1985 Satellite Directory
Phillips Publishing Inc., Suite 1200N, 7315 Wisconsin Ave., Bethesda, MD. 20814, USA, 936pp, 1985, $197.

More than 15,000 entries describe almost every company involved in the communications satellite industry in some way today. Over 11,000 licensed Earth stations are listed, along with detailed listings of carriers and system operators, hardware and soft-ware suppliers, business and information services, technical services, teleconferencing services, communications attorneys, programming services, international vendors, regulatory agencies, distributors and branch offices, and US government agencies.

It is fully cross-referenced and indexed and contains detailed technical profiles of each operational satellite, orbital assignment tables, lists of applicants for satellite systems, DBS allocations and revised orbital assignments reflecting FCC 2° spacing order.

Space Stamps
L. Malz, American Topical Association, P.O. Box 630, Johnstown, PA 15907, USA, 86pp, 1985, $11.

The conquest of space has captured the imagination of individuals throughout the world. Space stamps are so easily accessible that any collector can sit in his living room and know that he has stamps which document these epic events and, to ensure an even more adequate coverage, this handbook lists all known space stamps and souvenir sheets, some 6000 or so, of which the UK has contributed 7, issued by all countries of the world and arranged in alphabetical order. Within each country stamps are set out in chronological order, by year of issue, followed by various catalogue numbers and brief descriptions.

Selected astronomy issues have also been included e.g. observatories, planetariums, Copernicus, Kepler, Galileo, etc. with military rockets added for the benefit of those interested in this area.

The handbook also contains text describing spacecraft, missions, programs and personalities - facts presenting a wealth of interesting information.

The Optical Papers of Isaac Newton, Vol I The Optical Lectures 1670-72
Ed. A.E. Shapiro, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1984, 627pp, £75.

This, the first of three planned volumes, contains the 'optical lectures' delivered at Cambridge University between 1670-1672 during which Newton chose to expound his revolutionary new theory that sunlight consists of rays of different colours, each unequally refracted, together with mathematical and experimental accounts of his theory of colour and refraction.

These lectures formed Newton's first major scientific treatise and, consequently, represent a crucial link between his early years of discovery and his mature investigations and publications.

This edition of optical lectures was complicated by the existence of Newton's two significantly different versions, one apparently a first draft and the other a major revision. Combining the two was impossible so the decision was made to include both, together with optical correspondence, notes, essays and calculations, with translation and commentary.

The present volume thus falls into two parts. In the first, devoted to colour, Newton demonstrates his new theory with a large number of (often ingenious) experiments and then applies the theory to explain a variety of phenomena e.g. the colours produced by prisms.

In the second part, devoted to refraction, he describes various ways of measuring the refractions of fluids and solids and then attempts to develop a mathematical theory of refraction dispersion, which makes significant contributions to the study of geometrical objects.

Fundamental as these optical investigations were, they did not, however, amount to a new science based on novel principles, as was the case with his contributions to mechanics and mathematics.

The Jodrell Bank Telescopes
B. Lovell, Oxford University Press, Walton Street, Oxford OX2 6DP, 1985, 292pp, £15.

The author, who has provided two earlier books on the development of the radio telecopes at Jodrell Bank *viz The Story of Jodrell Bank,* (1968) and *Out of the Zenith,* (1973) now develops his theme to include the background to the concepts and constructions at Jodrell Bank with a detailed account of the discussions attending every issue.

His book is not concerned with results from radio telescopes nor, necessarily, with the principles involved; it is concerned solely with the events surrounding those instruments either constructed or envisaged for use at Jodrell Bank and thus provides an unusual insight into the tortuous negotiations needed to bring such matters to fruition.

The book is remarkably detailed, specifying the dates and personalities and figures discussed at each stage, prepared by an author who was not only deeply involved in every aspect but to whom each decision was of considerable importance. Those financial and political struggles which take place when large and expensive research projects are planned are normally screened from public view. Here they are spelled out as they occurred during two critical decades in astronomy i.e. the period from 1960 to 1980. It is interesting to read about visionary schemes for radio telescopes of unprecedented size, besides the events which led to their non-implementation. There is little in here to suggest that science is above politics: indeed, the implication is that science is as part of the political scene as is every other field.

Theory and Experiment in Gravitational Physics
C.M. Will, CUP, The Edinburgh Building, Shaftesbury Rd, Cambridge, CB2 2RU, 342pp, S/C £15, 1985.

This book offers a comprehensive survey of the intensive research and testing of general relativity that has been conducted over the past two decades. As a foundation for this survey, the book first introduces the important principles of gravitation theory, developing the mathematical formalism that is necessary to carry out specific computations so that theoretical predictions can be compared with experimental findings. It provides an up-to-date survey of experimental results, not only for Einstein's 'classical' tests such as the deflection of light and the perihelion shift of Mercury, but also for new Solar System tests, never envisaged by Einstein, that make use of the high-precision space technology of the 1960's and 1970's. The book goes on to explore new areas for testing gravitation theory in cosmology, black holes, neutron stars and gravitation waves. Included is a systematic account of the remarkable 'binary pulsar' PSR1913 16, the radio pulsar discovered in a compact double-star system in 1974, which has recently yielded the first evidence for the existence of gravitational waves.

This volume is designed to be both a working tool for the researcher in gravitation theory and experiment and an introduction to the subject for the scientist interested in the empirical underpinnings of one of the great theories of the twentieth century.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Cepheids: Theories and Observations
Ed. B.F. Madore, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2BX, 1985, 300pp, £20.

This volume contains the proceedings of a Colloquium which marked the 200th Anniversary of the discovery of Cepheid variables for, on 10 September 1784, Edward Piggot established the variability of the star we know as η Aquilae and, on the very same night, his friend John Goodricke found Beta Lyrae also. Both Piggot and his father were members of a well-connected family with a strong interest in astronomy, referring to themselves whimsically as 'Gentlemen Astronomers,' establishing a considerable private observatory in York.

Goodricke was an assidious observer, a characteristic which probably led to his death. Following his discovery of Delta Cephei's variability in late 1784, he observered it no less than 100 times in the first 10 months of 1785, a record for the English climate, but, early in 1786, he contracted pneumonia 'in the consequence of exposure to night air in astronomical observation' and died shortly afterwards, at the age of only 21.

In the two centuries which have since elapsed the study of Cepheids, and pulsating stars generally, has become an important field in astronomy, with the usefulness of Cepheids as distance indicators amply demonstrated by the flood of papers which appear on that topic alone every year. Consequently, the present volume, which seeks to update our knowledge of these important objects is much to be commended.

Cepheids range from young, massive stars (population 1) to old, low-mass population 2 stars - a distinction recognised now for more than three decades. As this volume shows cepheids in globular clusters are being carefully studied and compared with those nearer our Sun. Near-infrared photometry of Cepheids in some of our local group of galaxies is being used to determine new and independent distances to these objects. In fact, the advent of modern infrared techniques has led to a significant improvement in our estimates of their distances.

Principles of Remote Sensing
P.J. Curran, Longman Group Ltd., Longman House, Burnt Mill, Harlow, Essex, 1985, 282pp, £11.95.

Remote sensing of the Earth is one of the fastest-growing, most exciting and powerful techniques available to scientists concerned with environmental questions in fields as diverse as geology, geography, agriculture, mineral resources, biology, forestry, oceanography, meteorology, archaeology and military planning and strategy. This volume provides an up-to-date synthesis of the fundamental principles of remote sensing, as well as outlining many current applications.

The volume is well prepared and will be invaluable in meeting the needs of an increasing number of undergraduate and graduate courses in remote sensing, now taught to students with widely diverse backgrounds.

DO YOU REMEMBER?

25 Years Ago...
16 May 1960. A two-day conference begins at NASA's Langley Research Center to discuss space rendezvous, resulting in NASA centres being urged to develop various manned rendezvous techniques for further study.

20 Years Ago...
7 June 1965. Gemini 4 with astronauts McDivitt and White aboard splashes down 81 km off target in the Atlantic. The otherwise successful mission saw White perform the first American spacewalk, lasting twenty one minutes.

15 Years Ago...
1 June 1970. Cosmonauts Nikolayev and Sevastyanov are launched aboard Soyuz 9 on a 17 day mission. This crew set a new space endurance record, breaking Gemini 7's 14 days in 1965.

10 Years Ago...
8 June 1975. Venera 9 is launched from Tyuratam by a SL-13 Proton rocket towards Venus. It became the first spacecraft to send to Earth a picture from the surface of another planet.

5 Years Ago...
26 May 1980. Soyuz 36 with cosmonauts Kubasov and Farkas (Hungarian) aboard is launched on an eight day mission to Salyut 6. The two cosmonauts conducted experiments with Salyut's long-stay crew before returning to Earth in Soyuz 35.

K.T. WILSON

EDITORIAL *Continued from p.241.*

necessary. Proof of this arose when *Discovery* recovered the Palapa and Westar 6 communications satellites. The economies were obvious. For an outlay of $6 million, a total satellite package costing $140 million was recovered for re-launch. Moreover, the underlying reasons for the original failures could be unambiguously determined by examination of the recovered satellites. None of this would have been possible without the direct deployment of men in space. Even so, the carefully designed tools for the job failed in certain areas and it was only through direct 'on the spot' action that the vehicles actually *were* recovered. Mechanical improvisation of this sort has no counterpart in unmanned spacecraft: if the Shuttle had not existed then $140 million of satellite equipment would have been lost, as has occurred with other satellites in the past.

Satellites are growing larger and more complex all the time, possibly to the point where complete communications modules may be assembled in space. Only men could do that, which might make manned space flight one of the most profitable ventures yet.

A Manned Space Station

This is the next logical step after the relatively short, but extremely useful, Shuttle flights. There is an excellent case for using the Shuttle to place unmanned experimental microgravity platforms in space (e.g. Eureca), but a permanent manned platform opens up enormous additional options. Once again, the ability of a 'man on the spot' to improvise will hold the key to much successful operation.

An interesting counterpart to the mission durations' expected and the method of operation used for the Shuttle exists with the operation and repair of large ocean-going ships, whereby sections of the ship are shut down, repairs effected and the ship put under way again. Something similar has already been carried out in space by the USSR on Salyuts 6 and 7, as reported in *Spaceflight,* whereby repairs in orbit contributed considerably to the success of the missions.

The USA is planning to orbit a Manned Space Station by 1992. Although the US Government is expected to foot the major part of the bill private industry will also undoubtedly contribute. Indeed, a major contribution has already been made by one US combine. If such a station were fitted with even moderate satellite repair facilities, the enormous cost of retrieval, return to Earth and re-launch would be saved. Not only that, but the effective 'down time' of the satellite would be considerably reduced, thereby saving yet more.

A nation possessing such repair facilities would thus have a keen edge over those forced to rely on unmanned launchers alone. This is yet another reason why Europe should join the US Manned Space Station programme. In the longer term it may not be able to afford to stay out.

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Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01-735 3160.

NOTICES OF MEETINGS

Lecture

Theme: **COHERENT LIGHT FROM SUPERNOVAE**
By A.T. Lawton
President of the Society

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **15 May 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

One-day Forum

To be held in the Society's Conference Room, 27/29 South Lambeth Rd, London, SW8 1SZ on **Saturday, 1 June 1985**, 10.00 a.m. to 5.00 p.m.

Topic: **THE SOVIET SPACE PROGRAMME**

Subjects will include :

History of the USSR Lunar Programme

Cosmonaut Update

Soviet EVA Experiments

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

Lecture

Title: **SATELLITE INSURANCE**
By R Buckland

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **12 June 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time, enclosing a stamped addressed envelope.

Lecture

Theme: **METEORITES: SURVIVORS OF THE EARLY SOLAR SYSTEM**
By Dr. A.L. Graham
Dept. of Mineralogy, British Museum

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **18 September 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

36th IAF Congress

The 36th Congress of the International Astronautical Federation will be held in Stockholm, Sweden on **7-12 October 1985.** The theme is:

PEACEFUL SPACE AND GLOBAL PROBLEMS OF MANKIND

Members of the Society wishing to present papers are asked to notify Dr. L.R. Shepherd, Chairman of the BIS International Liaison Committee at Society HQ as soon as possible. Members wishing to present papers to the IAF Student Conference must submit them through the Society.

Lecture

Theme: **THE OORT COMETARY CLOUD: PROBLEMS AND PERSPECTIVES**
By Dr. M.E. Bailey
University of Manchester

The physical structures of comets, observations bearing on their sites of formation and the usual steady-state 'Oort Cloud' theory of cometary origins will be reviewed. Several apparently severe problems for this general picture will then be described, emphasising that the 'Solar System vs Interstellar' debate continues and the validity of the steady-state Solar System model remains unresolved.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on **30 October 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture

Theme: **OUR PRESENT KNOWLEDGE OF THE ASTEROIDS**
By Prof. A.J. Meadows
University of Leicester

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **20 November 1985**, 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates: 15 May 1985
12 Jun 1985

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

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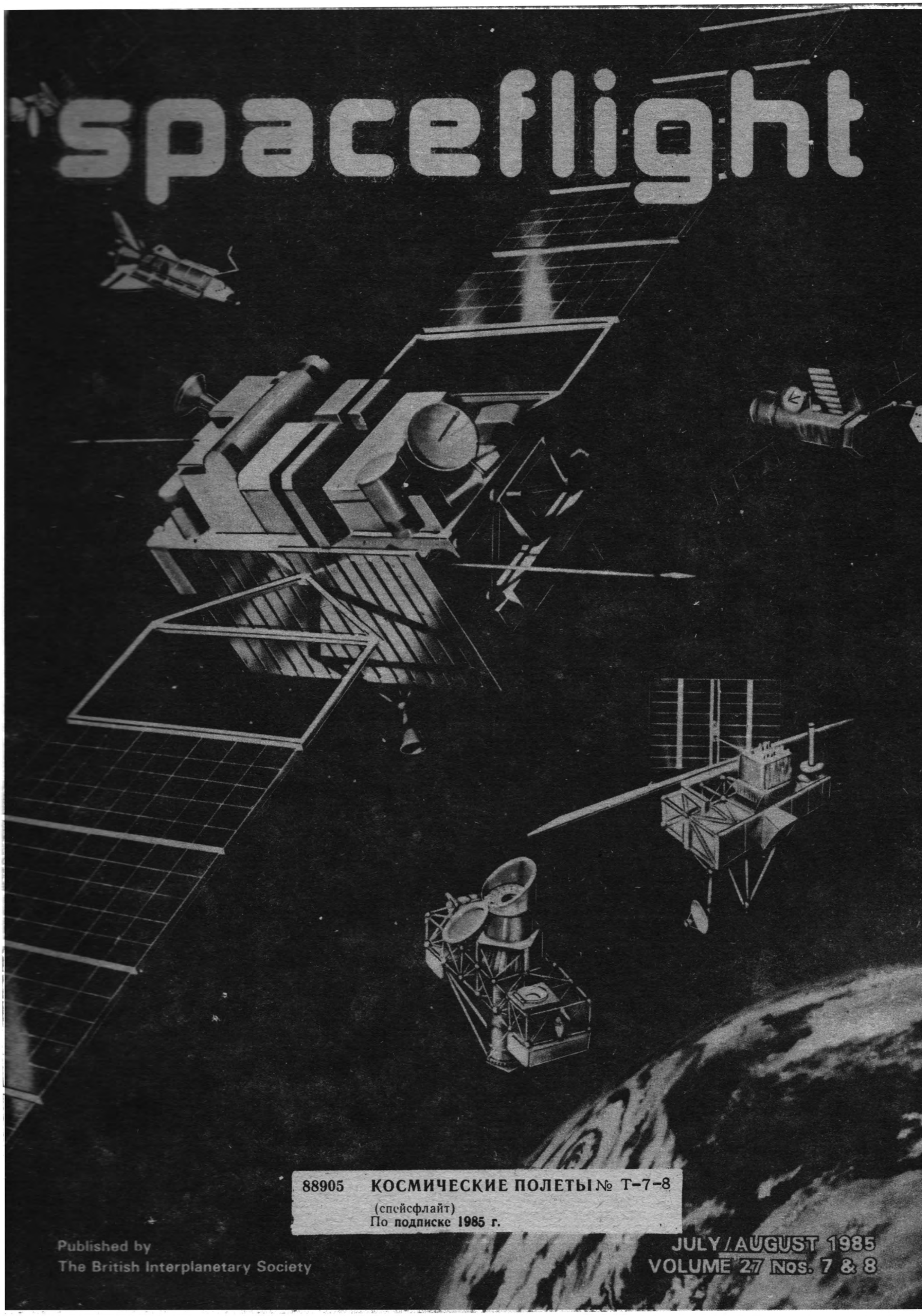

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По подписке 1985 г.

Published by
The British Interplanetary Society

JULY / AUGUST 1985
VOLUME 27 Nos. 7 & 8

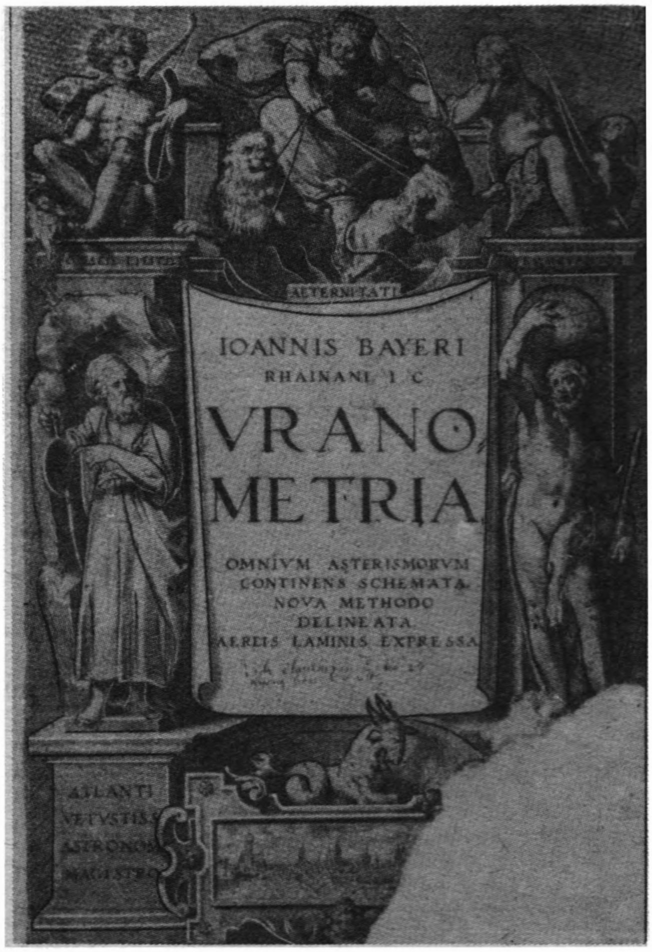
A PIECE OF ASTRONOMICAL HISTORY

As interesting articles in Spaceflight (March and June 1985) have related, the Society is fortunate to possess a unique copy of an early important astronomical star atlas and, in view of its importance, plans to issue facsimile copies in limited edition.

The Uranometria (Atlas of the Heavens) first appeared in the year 1603. Its author was a Bavarian lawyer, Johannes Bayer (1572-1605). It was such a boon to astronomers that it continued as a major work of reference throughout the 17th and 18th centuries.

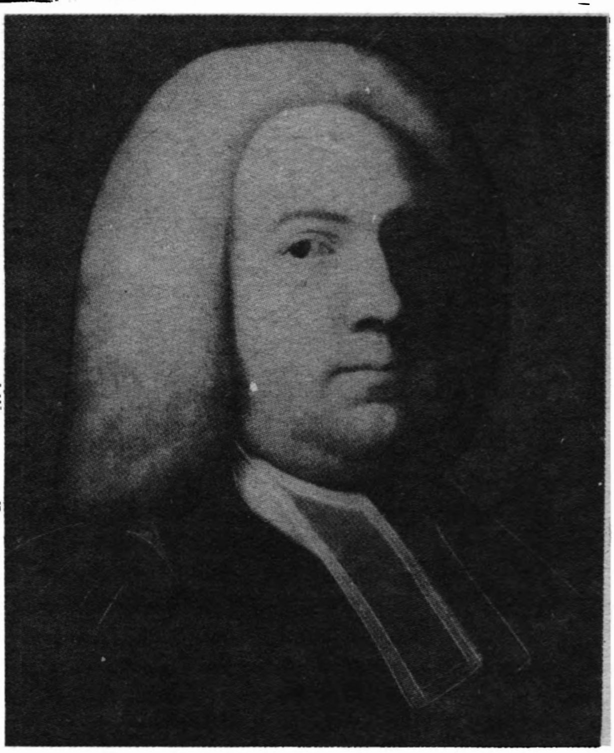
Basically, it consisted of a finely-engraved frontispiece with 51 copper-engraved star maps recording the approximate positions and magnitudes of some 500 stars observed by Bayer himself, in addition to those that had formed the renowned catalogue of the Danish astronomer, Tycho Brahe, only a year or two earlier.

The Society's copy is even more important than this. The Bayer star maps are interspersed with sheets of carefully-catalogued handwritten observations identifying the exact position of each star shown for Epoch 1747. It is apparent that this is the work of a dedicated astronomer of high calibre. Research is still continuing to identify who this mysterious observer might be but early candidates have included James Bradley (Third Astronomer Royal) and George Parker (Earl of Macclesfield), among a host of outstanding historical figures.



The title page of the Society's *Uranometria*.

James Bradley, Third Astronomer Royal. Was he the owner of the Society's *Uranometria*? *RGO*



The Bayer large-scale maps and accompanying writings will be reproduced, using the photographic plates carefully prepared in the initial stages of the investigations.

Only 500 copies will be made. Two versions will be available, one bound in Buckram (£160) and the other in calf vellum (£250). They will be identical in all respects except for the binding. Members interested in securing copies at a special pre-publication price should apply to the Executive Secretary at HQ.

Currently only a few good copies of the first edition of Uranometria are on the market. Their cost averages about £4,500 each though one auctioned in 1980 reached £6,500. These consist solely of the star maps with Latin wording on the reverse of each. Later editions are slightly cheaper, with one in good condition costing about £2,500.

These prices, of course, disregard the fact that our own facsimile, although with a slightly damaged frontispiece, has been more than doubled in size by the inclusion of page after page of additional observations. The enormous labour that went into making these observations underlines the outstanding character of the book.

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Managing Editor
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Assistant Editor
L. J. Carter

CONTENTS

PULLING TOGETHER

The 1985/86 time period is a critical one for space, both in Europe and the US. We always tend to think that we are standing at the crossroads of history but when one looks at the number of important space-related decisions that have to be taken in the next two years I believe that 1985 and 1986 have a real claim to be 'hinge' years.

There are four distinct streams:

1. In Europe there is a build up of national space activities - even the long-postponed formation of national space organisations in Italy and the UK;
2. There is a distinct broadening in the range of people with an interest in space - there are the first glimmerings of commercialisation (the making of money using space as opposed to conventional facilities or processes);
3. There is an increasing military use of space, and the Space Defense Initiative is likely to involve large amounts of funds and resources on both sides of the Atlantic;
4. We are on the threshold of the largest-ever international cooperative space venture: the Space Station. It will introduce new ways of exploiting space almost before we have learned how to handle the existing ones.

Each of these four streams will mean that money flows, both in the public and the private sectors, into space activities of some kind or other. It is already clear that their different objectives and motivations are bound to create frictions - not only between the US and Europe, but also within Europe.

We can look forward to two years in which the possibilities for upsets, mutual reproaches and the occasional bout of sulking are manifold. Unless we are wiser than we generally manage to be in such things, the tensions that will build up could very well spill over to have an effect outside the space arena, at a political as well as an industrial level.

The negotiations between Europe and the US on Space Station are going to be difficult - much more dificult than the technical interfaces and the like. They will require considerable patience on both sides, plus the realisation that there are major concessions to be made by both parties (hoping that it is not too optimistic to refer to Europe as a single party in this connection). The devil of it is that those who are not interested in space programmes (national or international), and those suspicious of international

Continued on p.336

COVER

An artist's impression of the European Retrievable Carrier satellite (Eureca), which will carry a variety of payloads after release from the Shuttle. The first flight is planned for 1988. Other examples of free-flying payloads are included.
ESA

Scientific Uses of a Space Station

Sir, Dr. Burt Edelson, in his evidence before the Space Science and Applications Subcommittee of the Committee on Science and Technology of the US House of Representatives, pointed out that both Space Science and Applications programmes will show enormous advances with the establishment of a manned Space Station in the 1990's. The elements that will make up the Space Station include pressurised laboratory modules, servicing accommodation and workshop facilities, and major polar orbiting platforms for coordinated Earth observations much more ambitious than anything hitherto. The need for long-term orbital observations, large power supplies, and high data rate capabilities, only possible with a Space Station and its associated platforms, is already recognised.

Besides this, the ability of a manned Space Station to deploy and recover Earth-orbiting spacecraft, repair and refurbishment operations, and the launch of deep-space missions opens up an enormous range of new activities. The successful repair of the Solar Max satellite was only a small example of how the scope, lifetime and scientific value of future missions will be increased by permanent human presence in space.

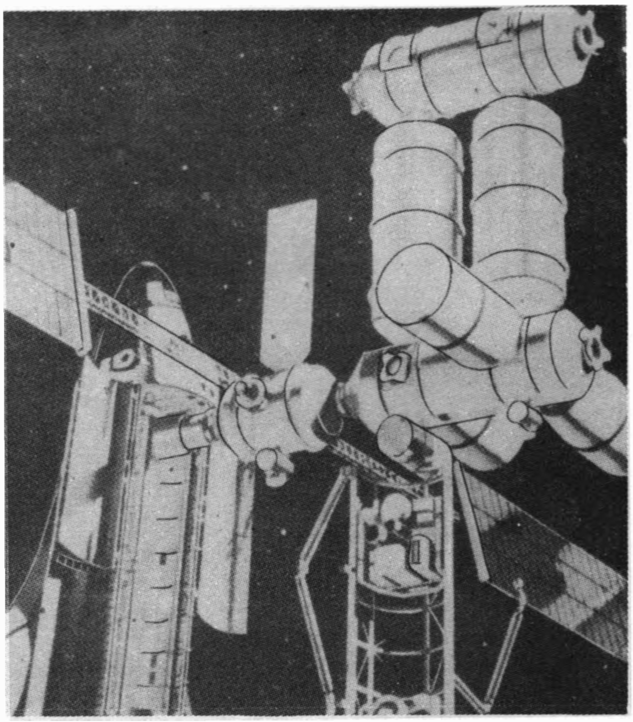
Dr. Edelson added that his office is studying in detail the requirements that space science activities for the 1990's would place on the Space Station and has established through the NASA Advisory Council a Task Force on the scientific use of the Space Station to provide advice on how to optimise its capabilities to support science and applications activities.

Many other studies are also being carried out on an individual discipline level. In astrophysics, for example, there are possibilities for large-scale on-orbit assembly of deployable antennae and astronomical facilities, besides servicing, parts changeout, and refurbishment of existing facilities on-orbit in order to avoid the costs of return to Earth and re-launch.

Planetary exploration projects associated with the Space Station include not only dedicated planetary telescopes but also instruments for possible detection of extrasolar planets. The Space Station may also make possible major, scientifically challenging missions by providing spacecraft staging operations and support laboratories for unmanned sample return missions to Mars and the nucleus of a comet.

Earth observations include a study of the requirements for an Earth Observing System on a polar platform. The Microgravity Science and Applications programme is developing plans for the transition of Shuttle-based instruments to the Space Station, as well as a Microgravity Research Center at the Lewis Research Center to test ground-based equipment in an environment that duplicates conditions on a Space Station as far as possible. This laboratory will later evolve into a ground-based testbed to check hardware designs as well as enhance the uses of the Space Station itself and provide a means whereby scientists and others can determine the suitability and possibilities of their equipment aboard the Space Station.

In Life Sciences there is a continuing need for biomedical research on space adaptation problems and long-term life support in space, with great possibilities in developing new generations of non-invasive diagnostic and treatment techniques as steps toward providing medical care and health maintenance capabilities for future long-term space travellers.



Apart from all this, there must be many ideas still awaiting exploitation. This is why NASA has also began a major two-year study of long-term future directions in space science, to take into account the new capabilities that the Space Station will provide.

P. GOODY
London

The Need for a Very Long Baseline

Sir, We have to probe the future constantly, even if tentatively, and even if some of us may not see some of the projects planned today actually come to fulfilment, just as Edmond Halley never saw the return of his famous comet.

On the other hand, we have been blessed with a concertina effect in seeing things - such as the exploration of distant worlds - once thought to lie thousands of years ahead, accomplished within our lifetimes.

The Society itself expresses this interest both in the past and in the future in many ways, e.g.

1. The past emerges in the Astronautics History issues of *JBIS* and with such matters as the Bayer and Bevis atlases and the exciting renaissance of thought by the 18th century astronomers, mirrored by a widespread interest on the part of many of our members in history and archaeology.

2. The future is shown by the challenges of interstellar travel that lie ahead, as posed by the *JBIS* red cover issues on the Interstellar Ark.

By projecting both back into the past and into the future, we try to lengthen our knowledge of human history, all of which influences our present attitudes and judgements and thus reduces our chance of error or the need, constantly, to go back and relearn the same things. It also allows us to go forward with a greater degree of certainty.

The longer the baseline, the better chances of human stability even though all we know of human history - goes as far back as possible and including all we presently conceive about the future - is probably still inadequate.

It is imperative for us to secure the longest line possible. Our own lifetime is such a tiny part of the spectrum.

E.M. WAINE
Sutton, Surrey

Why Bother?

Sir, The recent malfunction of the Syncom 4-3 communications satellite launched from *Discovery* during mission 51D demonstrated the remarkable flexibility of the Shuttle System. But how did the media respond? They took completely the wrong approach and trotted out their usual anti-space prejudices. Particularly offensive in this context was the Channel 4 Seven O'clock News on 17 April. The presenter suggested that this latest 'failure' (thereby giving the impression there had been a long string of them) put the whole existence of the Space Shuttle into doubt! It was a perfect demonstration of the points made in recent *Spaceflight* editorials and correspondence: ignorance is rife within the media.

A more appropriate line would have been that Syncom had malfunctioned through no fault of the Shuttle and it was only the human presence that provided an opportunity for on-the-spot repairs. An unmanned launch would not have had that capability.

It was claimed in several reports that the failure was a boost for Europe's Ariane. I fail to see how since, as with the loss of two satellites during Mission 41B in February 1984, no blame has been attached to the Shuttle.

In this country at least, Mission 51D was given only cursory coverage until problems arose. The inaccurate presentation makes me wonder - is it only space that gets run through the mangle every time or are we also served as badly in other areas? I would think that a major contributory factor is the dearth of science-educated people in the media.

BRIAN TURNER
London

New Soviet Launch Vehicles

Sir, There has recently been some open and conflicting discussion on the next generation of launch vehicles being developed in the Soviet Union.

Alan Bond and I have performed an analysis on these new launchers based on the envelopes given in the 1983 edition of the US Dept. of Defense report *Soviet Military Power*. This edition has been used as the only original source of reference material. This analysis must be regarded as provisional owing to the limited information available. However, it has resulted in the following conclusions.

1. The first stage of the medium lift launcher, now designated the SL-X-16, probably employs LOX/UDMH propellant. The analysis also confirms the use of this stage as the strap-on booster element for the larger vehicles.

2. The core stage of the heavy lift launcher and heavy lift shuttle now designated the SLW and SLW Shuttle, respectively, employs LOX/LH_2 propellant. This stage ignites at altitude at strap-on booster separation and therefore the engines are optimised for vacuum operation.

3. The payload of the SLW is 2 10 tonnes to a 180 km low Earth orbit assuming six strap-on boosters and a single stage core.

4. The SLW Shuttle employes the core and four strap-on boosters as a launcher which is capable of placing a payload of 155 tonnes to low Earth orbit. This mass includes the shuttle orbiter and its payload. Calculations based on the wing area of the orbiter, assuming a similar re-entry profile to the US vehicle, confirm this mass. These calculations used the revised orbiter configuration with a 'double delta' wing platform. The Soviet orbiter does not have main engines and therefore the mass of these and associated thrust structure are eliminated and available as payload. An empty orbiter mass of about 60 tonnes is suggested and compares with that of the US vehicle without engines. This results in a shuttle payload of 95 tonnes, confirming the DoD report values.

5. The 1985 edition of the DoD report gives a lift-off mass of the shuttle of 2000 tonnes, which is more realistic than the previous value of 1500 tonnes and compares with our analysis mass of 3000 tonnes.

6. The family of launchers has been optimised around the SLW heavy launcher. The SLW shuttle is, however, close to optimum design.

7. Both the strap-on boosters and the core employ high pressure pre-burner cycle engines.

The 1985 edition of the DoD report also states that the Cosmos lifting body test vehicle is apparently a scale model of a larger manned spaceplane. It adds that the Soviet Union is considering a manned expedition to Mars in 1992.

JOHN PARFITT
Hitchin, Herts

SNIPPETS

Samosata, not Samos

Sir, I noticed on p.98 of the March issue a facsimile of a letter by my old friend Arthur C. Clarke, wherein he states 'after all it has been a subject of every science fiction writer from Lucian of Samos in AD 160 onwards...' I think it is not inappropriate to point out that Lucian, better known as Lucianus, a Greek, did not originate from the island of Samos but from Samosata which then belonged to Syria but now is incorporated into Turkey.

CONSTANTINE GENERALES
New York

The Argument Goes On...

Sir, In the March issue (p.136) Klaus Iserland of Arianespace is quoted as saying, 'launching an unmanned spacecraft with a manned vehicle [i.e. Space Shuttle] is pure lunacy.' I submit that spending millions of marks, francs, pounds etc to develop and launch an unmanned rocket only to dump it in the Atlantic - that's lunacy!

ROBERT TUTTLE
New York

The Editor is always interested in receiving items of correspondence, notes, comments, or reviews for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine. The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.

Non-Existent Spaceships

Sir, Does Mr. Non's collection include the wingless 'aeromotor,' designed to travel at 600 mph, described in *The Daily Record* of 11 September 1929?

This was based on the startling claim by Mr. W.D. Verschoyle of Sligo, Ireland 'an inventor whose work is already known throughout the world' that gravity can be controlled electrically. Verschoyle proposed machines able to rise in the air to any height regardless of weight and without gas, wings or helicopters and travel over any distances - all due to the discovery of a means whereby gravity can be reduced at will so that heavy objects can be made to hang in the air without any visible means of support, simply by the movement of a switch.

Verschoyle's aeromotor (anti-gravity ship) was a long steel machine of large proportions, without rockets, planes or such familiar appliances and with no technical need to economise in space or weight either. Comfort and safety could be fully provided for both passengers and crew because machines could be built to almost any size, varying from solo ships to 500-passenger liners.

The inventor was reported to have said that he was principally concerned with such machines to assist in relieving the congested traffic of the arterial roads. He added that a patent had been applied for and he would shortly be going full steam ahead with the experiments with practical demonstrations carried out before many months had elapsed.

Wisely, he refused to describe his invention in more detail, explaining 'I do not care to say much about the principle for there are many keen brains in search of what I have found' but, when applied, 'it will probably be the most disturbing factor that has ever been introduced into both the worlds of science and finance.'

The disturbance turned out to be minimal.

A.B. GEDDES
Peel, Isle of Man

Mr. Non replies:

Verschoyle's claims were dealt with more than kindly by A.V. Cleaver in his article 'Interplanetary Flight: is the rocket the only answer?' (*JBIS* June 1947, p.137). Cleaver secured the loan of Verschoyle's notebooks following his death in 1944 and repeated his experiments. He found that Verschoyle had simply been misled: the 'lift' experienced was merely an electrostatic effect.

TELEGRAMS, "AQUILÆ, LONDON".
TELEPHONE Nos REGENT 4024 & 4026

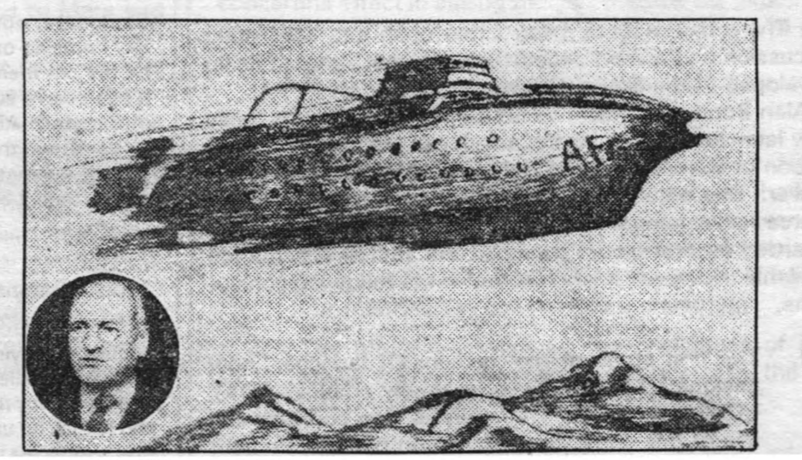
W. D. Verschoyle.
address Tanrago
Ballysodare
Co Sligo
Ireland.

ROYAL SOCIETIES CLUB.
ST. JAMES'S STREET,
S.W.1.

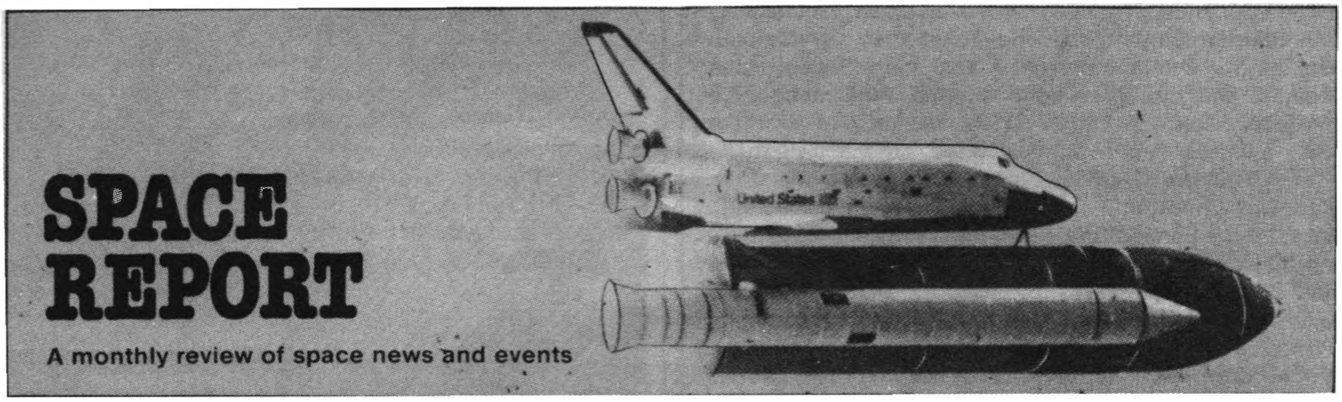
Aug 7 1929.

A. B. Geddes Esq.
Renfrew

Dear Sir.
Replying to yours of 3rd inst. I am sending you material which you can work up in your own way and make what you can out of it.
I have been working for well over 20 years, off and on when funds allowed, on this subject, and in the patent just applied for the result is embodied in a few lines, and is of course secret as yet. I shall shortly be going ahead full blast with the experiments and hope that a practical demonstration will be safe before many months.
The principle I do not care to say too much about, for there are many keen brains in search of what I have found, but the principle when applied will probably be the most disturbing factor that has ever been introduced into both the worlds of science and finance.
As far as I can see at present it will be possible to make my machine any size between a one and a 500 passenger service. The speed will be adjustable between a yard and 10 miles per minute and it will be able to rise up or descend vertically from any desired location. There will be no propellers, rockets, planes or gas bags; the whole will be constructed of metal, and as there will be no technical need to economise in space or weight, comfort and safety can be fully provided for.
~~Just as~~ The motor car has reorganised the world and spread the great cities over a wider area much to the benefit of the inhabitants, & this machine will continue and extend this good work. Draw a circle of 400 miles radius round London and anywhere within that circle will be called 1 hour from the city.
All this will give you material for a good article, which I trust will produce satisfactory financial results.
Yours faithfully
W. D. Verschoyle



Above: Mr. Geddes' illustration was used with his article in the 11 September 1929 issue of *The Daily Record* recording Verschoyle's claims. Inserted is a picture of the 'inventor' himself.



COLUMBUS: A STEP FORWARD

Among the many ambitious decisions taken by the ESA Member State Ministers at the Council meeting in January 1985, perhaps one of the most exciting was their acceptance of the offer to participate in the US Space Station programme on the understanding that Europe was given responsibility for the design, development, exploitation and evolution of one or several important elements of the Station.

A new milestone was reached in late April with the Columbus Preparatory Programme under which Space Station studies are being carried out. Following negotiations between ESA and NASA, a plan of activities to be undertaken on both sides of the Atlantic over the next two years has been drawn up. Each partner will carry out, in parallel, detailed definition studies (Phase B studies) on a number of Space Station elements.

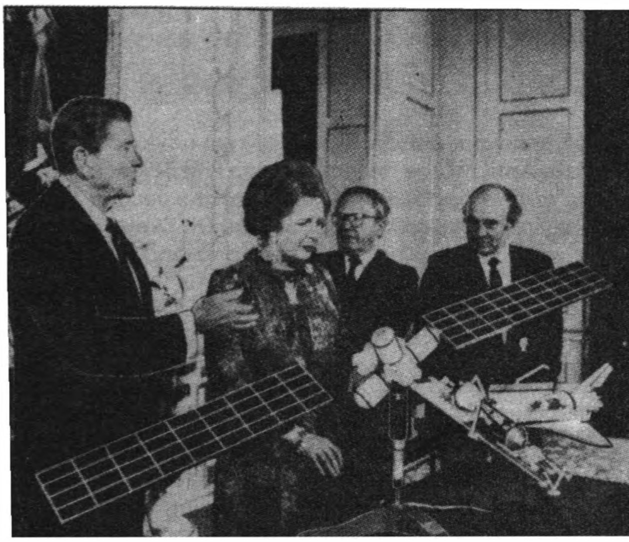
Potential elements of ESA's contribution could consist of a pressurised module that could be used as a manned laboratory, free-flying payload carriers for both low inclination and polar orbits for experimental purposes, a servicing vehicle and a resources module that could provide both the pressurised module and the platform with electric power, and cooling and stabilising systems. In addition, ESA-managed studies will also cover such aspects as ground facilities for mission preparation and support and a data transmission system.

The ESA Council, at its meeting on 24/25 April, unanimously authorised the Director General to sign the Memorandum of Understanding with NASA, which lays down the terms and conditions under which the cooperative effort will be carried out. These European Phase B studies will cost about $65 million.

SPACE STATION LIFE SCIENCES

Boeing Aerospace Company was awarded a $139,500 study extension by NASA in April to provide definitions and conceptual designs of accommodations for life sciences research facilities aboard the Space Station.

The award follows Boeing's successful Part One accommodation study, which concluded in December 1984. That examined the scientific and hardware accommodations requirements of a life sciences facility in which the effects of low and zero gravity on animals and plants could be evaluated. Such laboratory accommodations might resemble other potential Space Station modules in size. The five-month Part Two study 'will look at options to accommodating both plant and animal experiments in the Space Station,' said Dick Olson, Space Station life support crew systems manager. 'A determination of what experiments are feasible will be recognised in the facility's conceptual design.


President Reagan and Mrs. Thatcher study a Space Station model during the June 1984 economic summit in London.

The life sciences study will investigate designs leading toward eventual construction of a module that will allow scientists to perform biological research on non-human specimens such as rats, mice, squirrel monkeys, rhesus monkeys, varieties of plants and microscopic life, said Boeing biologist Edith Gustan.

'There are a couple of issues we will confront; one deals with the use of a centrifuge the full diameter of the module,' Gustan said. 'The reason for a centrifuge is to provide an Earth-gravity environment for control references. We also need to find a way to get air and water to the specimens.'

SPACE SHUTTLE

FIRST VANDENBERG SHUTTLE

The first Shuttle launch from the Vandenberg Air Force Base in California will take place no earlier than 29 January 1986 and possibly two months later, writes Nicholas Steggall. The launch date was previously set for 15 October 1985. The delay will maintain the present Shuttle launch manifest and also provide extra time for preparing the payload. The second launch, scheduled for early September 1986, is not expected to be affected.

The Orbiter for the first launch, *Discovery,* will remain operational in Florida before being delivered to Vandenberg in early September. The delay did not affect the delivery of the External Tank, which arrived after a 29 day voyage from New Orleans on 28 February.

The Vandenberg facilities have been undergoing checks with Shuttle components. The 'Pathfinder' vehicle consists of the Orbiter *Enterprise,* two inert Solid Rocket Boosters and the lightweight External Tank number 16 (LWT-16). Stacking began on the launch pad with the SRBs and the tank was then lifted between them by cranes. After the 27 km journey from the Orbiter Maintainance and Checkout Facility, *Enterprise* was lifted into place. US Air Force officials said that 'stacking the Shuttle and major Orbiter components on the launch pad rather than in a vertical assembly building provides greater flexibility for ground crews in processing Shuttle systems.'

The ice suppression system was also tested. Unique to the California site, it was devised to prevent ice formation during loading of the External Tank: hot air is blown over the liquid hydrogen area by two jet engines adjacent to the pad.

PAYLOAD SPECIALISTS CHOSEN

NASA announced the selection of two payload specialists in late April for the initial Spacelab Life Sciences flight and one of two payload specialists for the second flight.

The payload specialists for SLS-1 are Dr. Drew Gaffney, 37, an associate professor of medicine and cardiology and director of echocardiography at the University of Texas Health Science Center, Southwestern Medical School, Dallas; and Dr. Robert Phillips, 56, a veterinarian and professor of physiology and nutrition at Colorado State University, Ft. Collins.

The selections were made by NASA Administrator James Beggs on the recommendation of Dr. Burton Edelson, Associate Administrator for Space Science and Applications and the Investigators Working Group, comprising principal investigators for the flights.

'These two flights are the first fully dedicated life sciences missions to be flown aboard the Space Shuttle,' Edelson said. 'This is a significant effort in improving our knowledge of living beings in the space environment and a major step in preparing men and women for life aboard the Space Station scheduled for launch in the early 1990's,' he added.

A fourth payload specialist candidate, for the SLS-2 mission, was due to be selected to begin training with the others.

Criteria for the selection included an advanced degree in life sciences or a medical degree and significant recent experience in laboratory research. Almost 50 candidates were nominated by the two flight's 23 principal investigators. The candidates underwent rigorous investigation by the group's Payload Specialist Selection Committee in late 1983 and final recommendations were made to NASA Headquarters in mid-April 1985.

SLS-1 is to be ready for launch as early as spring 1986, SLS-2 is scheduled for early 1987. Shuttle 61D/SLS-1 will be commanded by veteran astronaut Vance Brand; pilots will be David Griggs and Dr. John Fabian. The mission specialists will be Drs. Rhea Seddon and James Bagian. The flight crew for the 71G/SLS-2 has yet to be selected.

BIS FELLOW AWARDED

Dale Kornfeld, a scientists at NASA's Marshall Space Flight Center and a BIS Fellow, was named in March as 'NASA Inventor of the Year' for his work on the Monodisperse Latex Reactor, which has flown with great success on five Shuttle missions.

Dale Kornfeld (right) with astronaut Jack Lousma with the MLR in preparation for the third Shuttle mission. *NASA*

The MLR produces tiny uniformly-sized latex spheres of sizes not possible on the Earth's surface because of gravitational effects. The spheres are in demand for use in industrial and medical research and as a standard for calibrating precise scientific instruments. The polystyrene spheres will be the first 'made-in-space' product to reach the market when they become commercially available this summer as the US national 10 micron (10^{-5} m) Standard Reference Material.

Mr. Kornfeld invented the space processing system along with three researchers from Lehigh University. Dale told *Spaceflight,* 'My award was a very nice surprise. We still have three more flights planned, but probably not until Mission 61B in November for our next one.'

The spheres have been produced at up to 30 microns in size - beyond what is possible on Earth - and it is hoped that the remaining flights will take that up to 100 microns. It is calculated that a single flight can produce $2-3 million's worth of latex from the small unit carried in the mid-deck area.

TEACHER ON SHUTTLE

When the application period for NASA's 'Teacher in Space Project' closed on 1 February, 10,690 teachers had applied for a flight on the Shuttle, writes Nicholas Steggall. All the applicants were then screened by the US Council of Chief State School Officers review panel and the State review panels evaluated the remaining applicants to select two teachers per state on 1 May.

This left 118 nominees, including teachers from the District of Columbia, Puerto Rico, Virgin Islands territories and trusts of the US and Department of Defense and State-dependant Schools. A further evaluation will be made by a national review panel. All of the nominees will attend a teacher workshop and orientation programme

on 24-28 June. The national review panel will then select 10 semi-finalists in July for consideration by the NASA Space Flight Participant Evaluation Committee.

These 10 teachers will report to the Johnson Space Center for thorough medical examinations, in-depth briefings and interviews. The committee will then select who will undergo necessary training; the names of these finalists will be submitted to the NASA Administrator and the evaluation committee for them to select one primary and one back-up candidate for flight training. The flight is expected for late this year.

SATELLITES

NEW INMARSAT SATELLITES

British Aerospace were awarded a $150 million contract with Inmarsat, the International Maritime Satellite Organisation, in April for the first three of the second generation satellites of the global maritime communications system.

As prime contractor, British Aerospace will be responsible for the design and manufacture of the satellites but, in common with most international space contracts, will also manage a team of experienced aerospace companies. The major participants will be Hughes Aircraft Company, Matra and Fokker. The contract includes options for up to six further satellites, bringing the potential total value to about $400 million.

The specialised communications payload will be provided by Hughes of the United States, who have long experience of maritime communications satellite technology, having built Inmarsat's first communications satellites, the Marisat series, and supplied the Leasat spacecraft for the US Navy.

The current Inmarsat system includes BAe-supplied Marecs satellites that are in operation in the busy Atlantic and Pacific regions. There is rapid growth in the use of the system and during 1988 the first of the second generation satellites will need to be positioned in orbit.

The new spacecraft bus is based on the Eurostar platform, which is well into an extensive programme of development and test (it is a joint development by BAe and Matra in France). The first Inmarsat-2 is expected to be completed by mid-April 1988 for launch during June into its geostationary orbit over the Atlantic Ocean, about 36,000 km above the equator. It should then go into operation later that year. Production of the second and third satellites will follow at four-month intervals.

The new series will be three-axis stabilised satellites with a height of 2.557 m, length 1.586 m, width 1.480 m, span of solar arrays 15.23 m, launch mass 1160-1269 kg (depending on launch vehicle) and an in-orbit lifetime of 10 years. The communications payload, consisting of four transponders operating in C and L-band, will provide power sufficient for a minimum of 250 voice channels in the ship-shore direction and 125 channels shore/ship. However, it is expected that the actual number derived will be equivalent to up to 400 two-way voice circuits.

The satellites have been designed for launch aboard either an Ariane vehicle or the Shuttle. However, Inmarsat will consider other alternatives, including Atlas Centaur, Proton, Titan and Thor-Delta, before reaching a decision probably in mid-1985.

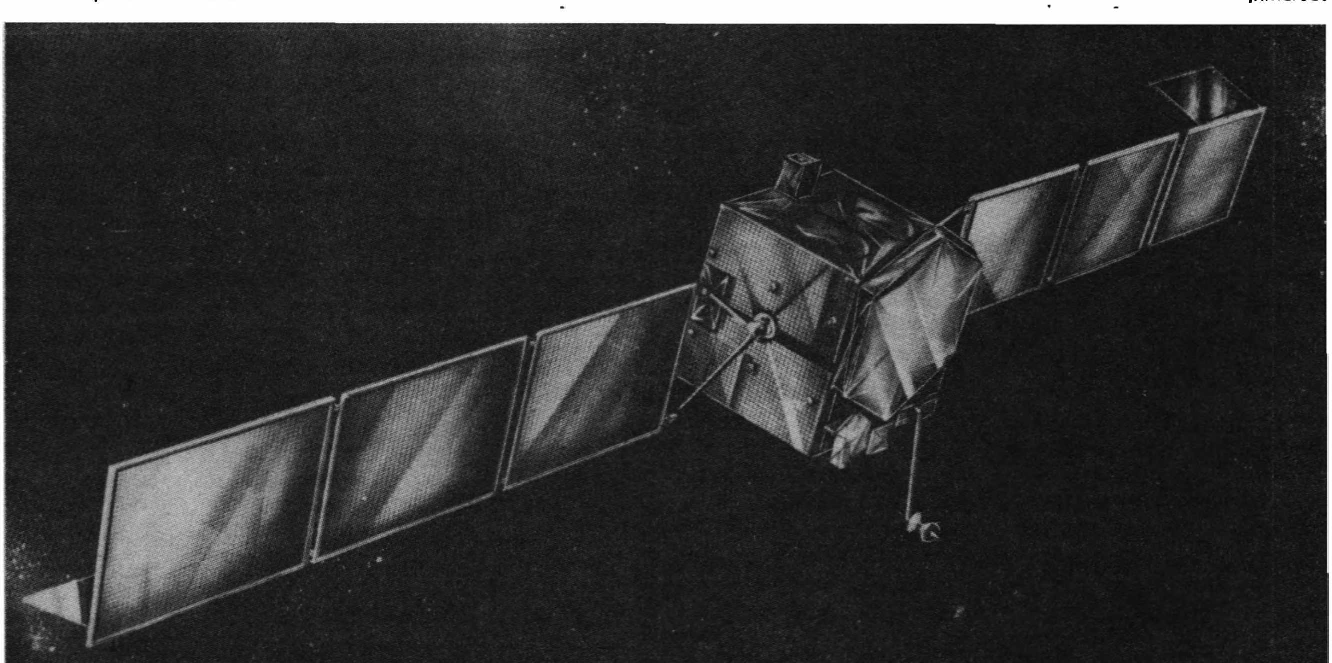
ATS-1 DRIFTS AWAY

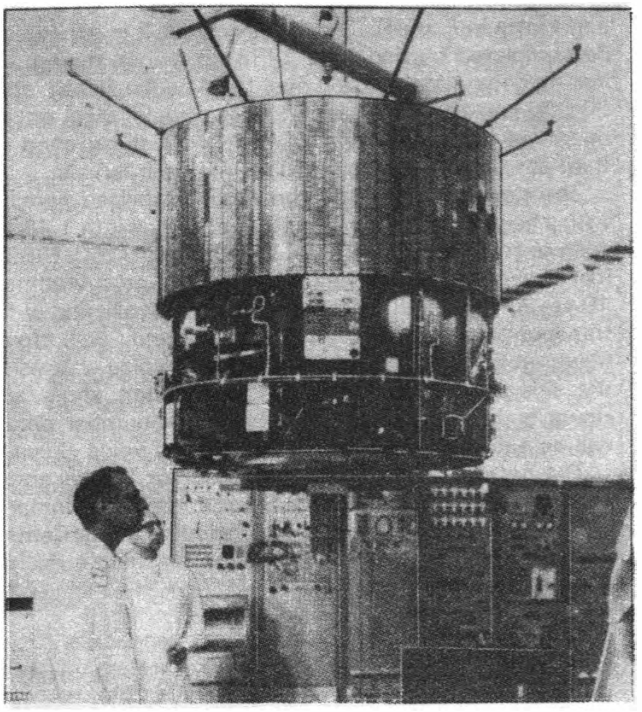
After more than 18 years of service, NASA's first Applications Technology Satellite (ATS-1) has failed to respond to commands to correct its eastward drift from its geostationary position over the Gilbert Islands in the western Pacific.

Robert Wales, ATS project operations director at NASA's Goddard Space Flight Center, reported that 'the ground control station at Hawaii can no longer keep ATS-1 at its present location and it will likely drift out of a useful orbital position in the next six months.'

Launched in December 1966, with an expected lifespan of three years, ATS-1 has most recently provided a voice and data communications capability to several information networks in the Pacific basin. The Pan Pacific Education and Communication Experiments by Satellite (Peacesat) programme, latterly the major user of ATS-1 services, will effectively dissolve with the eventual loss of the satellite. Educational, health, research, technology and community services have been transmitted through ATS-

Artist's impression of an Inmarsat 2 satellite. *Inmarsat*





The ATS-1 satellite was launched in 1966 for geostationary communications trials. *NASA*

1 to 23 autonomous terminals located in Hawaii, Cook Islands, the Mariane and Caroline Islands, Western and American Samoa, the Marshall Islands, Melanesia, New Zealand and Australia.

ATS-1 has compiled a notable record of achievements during its lifetime:

- First transmission of full-Earth, cloud cover pictures from geosynchronous orbit-forerunner of the hemispheric weather pictures seen on TV (1967).
- First transmission of real-time TV pictures (Apollo 4 splashdown) from the mid-Pacific (1967).
- Two-way communication tests with commercial airliners to determine aircraft orientation effects on satellite communications; a cooperative venture with the Federal Aviation Administration and the airlines (1967-1968).
- Transmission of electrocardiographs from Hawaii to New Zealand and from Alaska to the University of Washington (1973).
- Presentation of medical conferences over the Peacesat network consisting of 12 nations and the University of Hawaii (1971-1978).

The loss of ATS-1 will leave one other comparable satellite, ATS-3, in operation. It was launched in November 1967. Positioned in geostationary orbit over the Pacific Ocean, south of Mexico, ATS-3 covers the US, most of the Atlantic Ocean and a large part of the eastern Pacific, including Hawaii.

INTELSAT 5A IN ORBIT

Intelsat 5A-F10, eighth in the series of ten Intelsat 5-type international communications satellites, was launched from Cape Canaveral by an Atlas Centaur on 22 March. Atlas Centaur-63 was the second of the new stretched version of the vehicle, able to lift 159-227 kg more than the previous design (a total of 2,318 kg). The Atlas body has been extended by about 2.05 m, enabling it to carry more propellants.

While the Centaur upper stage remains basically the same size as before, it has undergone changes which include switching from a pump-fed to a pressure-fed main fuel system, changing from a hydrogen peroxide to a hydrazine attitude control system and the introduction of a silver insert in the interior of the rocket nozzle throat to increase performance. Silver is used because of its excellent heat conduction ability, allowing the nozzle to stay cooler.

This was the first launch of an Intelsat 5A by the Atlas Centaur. The 5As are similar to the 5s but they incorporate modifications to increase reliability and boost their communications-carrying capacity by 25%, from 12,000 to about 15,000 simultaneous telephone calls plus two TV programmes.

The satellite just launched weighed 2,013 kg with an in-orbit weight of 1,098 kg after the burn of the apogee kick motor. The three-axis stabilised spacecraft has a height of 6.4 m and measures 15.9 m (52 ft) across its extended solar panels. It was initially located over the equator at about the same longitude as Paris for several weeks of in-orbit testing prior to being brought into operation over the Atlantic Ocean.

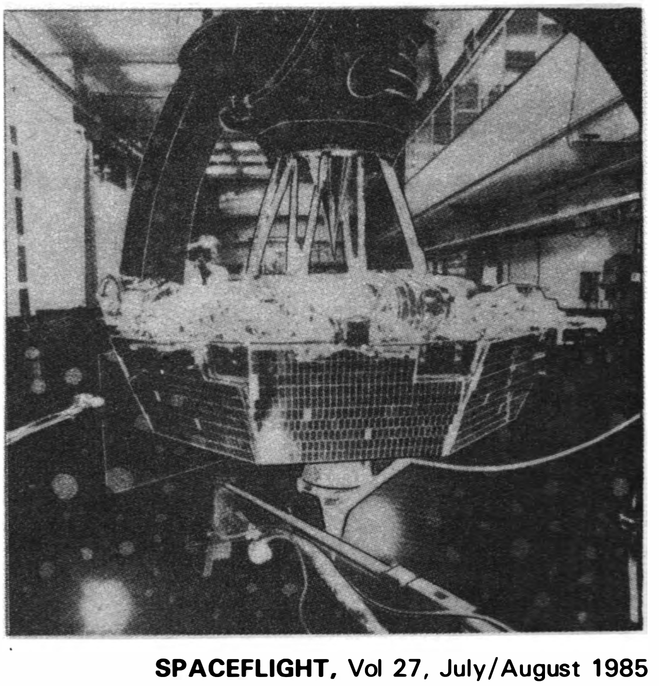
COMMUNICATIONS

COMMUNICATIONS GROWTH

A growing variety of applications coupled with a rapidly expanding network of private satellites is spurring large increase in the satellite communications market, notes a recent report by Frost & Sullivan Inc. Space segment revenues will rise continuously to 1994 to a market worth $3,600 million, a huge increase over 1984's $606 million market (figures in 1984 terms).

One reason for the growth in commercial satellites is the variety of uses. In the recent past, satellite usage was limited mostly to the major TV networks, but today

The Swedish Viking magnetospheric satellite will be launched with the French SPOT remote sensing satellite this autumn by an Ariane. The low-cost satellite, weighing 530 kg at launch, is built around the adaptor attaching SPOT to the final stage. Viking's payload includes two ultraviolet cameras to produce aurorae images in a Canadian experiment. The picture shows Viking under test at ESTEC in Holland. *Saab-Scania/Estec*



more than 60 cable TV services currently distribute their programming *via* satellites. Other new applications are waiting in the wings, including mobile radio transmission *via* satellite. In fact, says the report, there are more applications for spacecraft than available orbital slots, and not all applications are expected to be granted.

The total annual market for commercial satellites quadrupled from 1980 to 1984, from $256 million to more than $1000 million, and by 1994 it is expected to rise to almost $1,400 million. It is noted that growth will not be steady in all of the segments of the market throughout the forecast period. The authors state that 'if all launches were to be made as planned, a peak would be reached in 1987.'

Satellite sales, for example, will reach a market value of $1,600 million in 1987, up from 1984's $1,070 million. By the end of the 1994 forecast period, however, sales will fall back to $1,390 million.

Launch expenditures will likewise peak. Frost & Sullivan estimates the 1987 market at $1,300 million, up from 1984's $915 million. However, the 1994 market is predicted to drop back to $1,000 million.

NEW ZEALAND RECEIVING STATION

The New Zealand Minister for Science and Technology, Mr. Tizard, recently announced that the New Zealand Government intends to make funds available for an Earth resources satellite receiving station and the associated facilities for processing and disseminating the date. The project has been under consideration for some years but the recent positive recommendation of the NZ Communications Advisory Council succeeding in persuading Government to go ahead.

The project will be under the control of the newly-formed Division of Information Technology in the Department of Scientific and Industrial Research. Dr. Peter Ellis, with long-standing connections in the remote sensing field - he was previously in industry and academia in the UK - has been nominated Director of the Division.

OTHER NEWS

AEROBEE RETIRES

Aerobee, the sounding rocket that paved the way for manned space flights and deep probes into space, retired on 17 January, with its 1037th launch. The flight, from White Sands Missile Range in New Mexico, officially concluded a long and prodigious record that spanned more than 37 years.

Aerobee pioneered the use of high altitude photography to study cloud patterns and other meteorological phenomena. This work provided the stimulus for development of weather satellites. The first X-ray star was discovered with an Aerobee. Subsequent Aerobee flights disclosed a dozen more such stars and created a whole new field: X-ray astronomy. The first wide-angle ultraviolet photographs of star fields were taken from an Aerobee rocket and it was the first American space vehicle to carry mammals (monkeys and mice) into space and return them safely to Earth.

The Aerobee produced the first 'map' of the atmosphere, showing how temperatures and pressures varied with altitude and how density, composition and degrees of turbulence changed from one layer to another. This information is still used in preparing for space flights, particularly re-entry profiles.

MILESTONES

April 1985

1 It is revealed that the USSR is planning Mars, Venus and Moon probes over the next few years. Two probes will travel to Mars in 1988 to observe Phobos and Deimos at close quarters; a 1989/90 lunar polar orbiter will geochemically map the surface and two 1991 probes would investigate Venus and two asteroids (one possibly Vesta). US plans might now be revised.

6 Orbiter *Atlantis* is 'rolled out' at Rockwell's plant in California. *Columbia* is still being modified there and is due to be redelivered to NASA by 6 July.

8 The first Vandenberg Shuttle flight could slip to March or April 1986 to allow further launch team training.

12 Shuttle 51D (*Discovery*) is launched with seven-man crew.

13 Orbiter *Atlantis* is delivered to the Kennedy Space Center to be prepared for the September 51J military mission.

15 Orbiter *Challenger* is rolled out to pad 39A for the Spacelab 3 mission, scheduled for the 29th.

15 President Reagan has dropped plans for discussion with the Soviets for a joint Shuttle/Salyut mission, it is reported.

15 NASA awards contracts to Rockwell and McDonnell-Douglas for the definition and preliminary design of the Space Station structural framework and other elements.

16 The US and Canada sign a memorandum of understanding on Space Station Phase B studies. Initial agreements are expected with Europe and Japan in late April and on 1 May, respectively.

16 Hoffman and Griggs make an unscheduled EVA to attach 'fly-swats' to the robot arm on Shuttle 51D. Seddon uses them to trip a switch on Syncom 4-3 on the 17th but it remains dormant.

19 Shuttle *Discovery* lands at the Kennedy Space Center to end the 51D mission.

23 Today's Ariane V13 launch was earlier postponed to 7 May after a memory short circuit was discovered in the inertial platform of another vehicle.

24 Shuttle 51B/Spacelab 3 will be launched on 29 April, NASA announces, with a landing in California because of anomalies in the 51D landing in Florida.

25 The Ministry of Defence announce that Sqn. Ldr. Nigel Wood will be Britain's first astronaut, flying with Skynet 4A in June 1986. Lt. Cdr. Peter Longhurst will accompany Skynet 4B the following December. Major Richard Ferrimond and civilian Christopher Holmes will act as backups.

25 The ESA Council agrees to sign the Memorandum of Understanding with NASA for Phase B Space Station studies.

29 Shuttle *Challenger* is launched at 16.02 GMT for the 51B/Spacelab 3 mission.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

PHOTOGRAPHING HALLEY'S COMET

By H.J.P. Arnold*

Photographing Halley's comet when it appears in the skies towards the end of this year will not be a simple task. The author provides a guide to help the amateur.

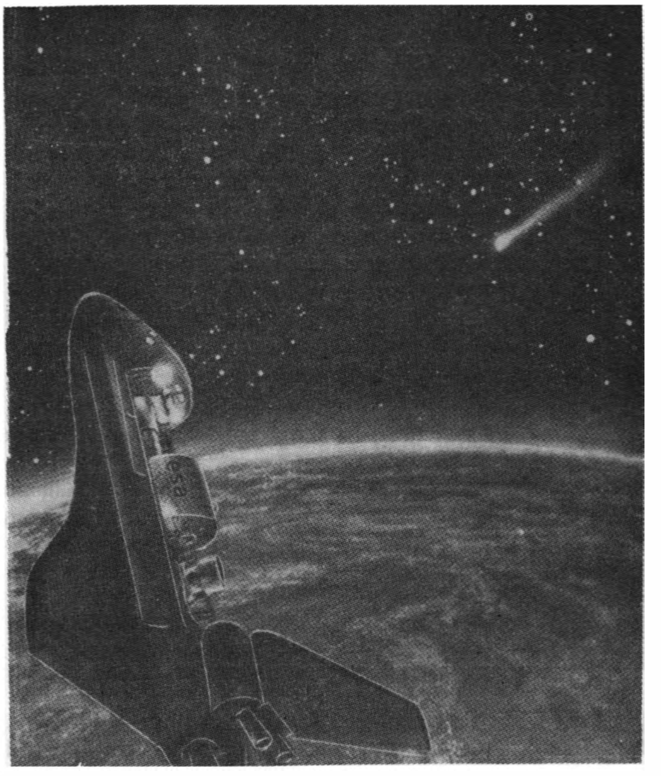
Introduction

Predicting how bright a comet is going to be is a difficult business. Many readers will doubtless remember the high expectations of Comet Kohoutek in 1973/74 - the first to be studied from a manned space station (Skylab) - and what a disappointment it was for the general public. The problem for this apparition of Halley's comet stems basically from the relative positions of the Sun, Earth and comet during the time around perihelion. The comet will be considerably further from Earth on both its incoming and outgoing legs than on many earlier visits, but worse still is the fact that for about three weeks around the time of perihelion on February 9 1986, when the comet will be at its brightest, it will be on the other side of the Sun from us and not observable.

Visibility

Current estimates are that Halley's comet will reach a magnitude of about 2.5 at its brightest - which is not too spectacular to say the least. Although it will be an object visible with amateur telescopes from about September/October 1985 and with binoculars from about mid-November, it will not become a naked eye object in dark skies until sometime in December, at the earliest. Incidentally, except where indicated otherwise, the discussion about viewing the comet refers to a latitude of approximately 50°N plus.

* Space Frontiers Ltd.

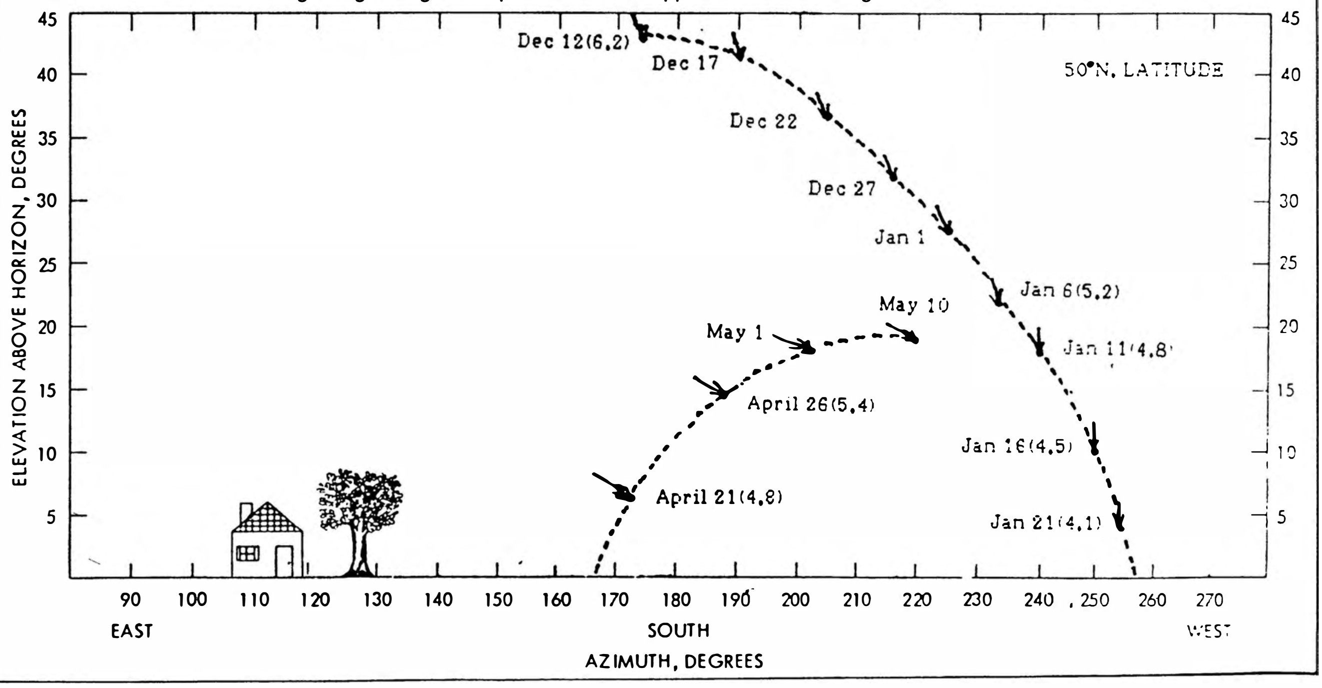


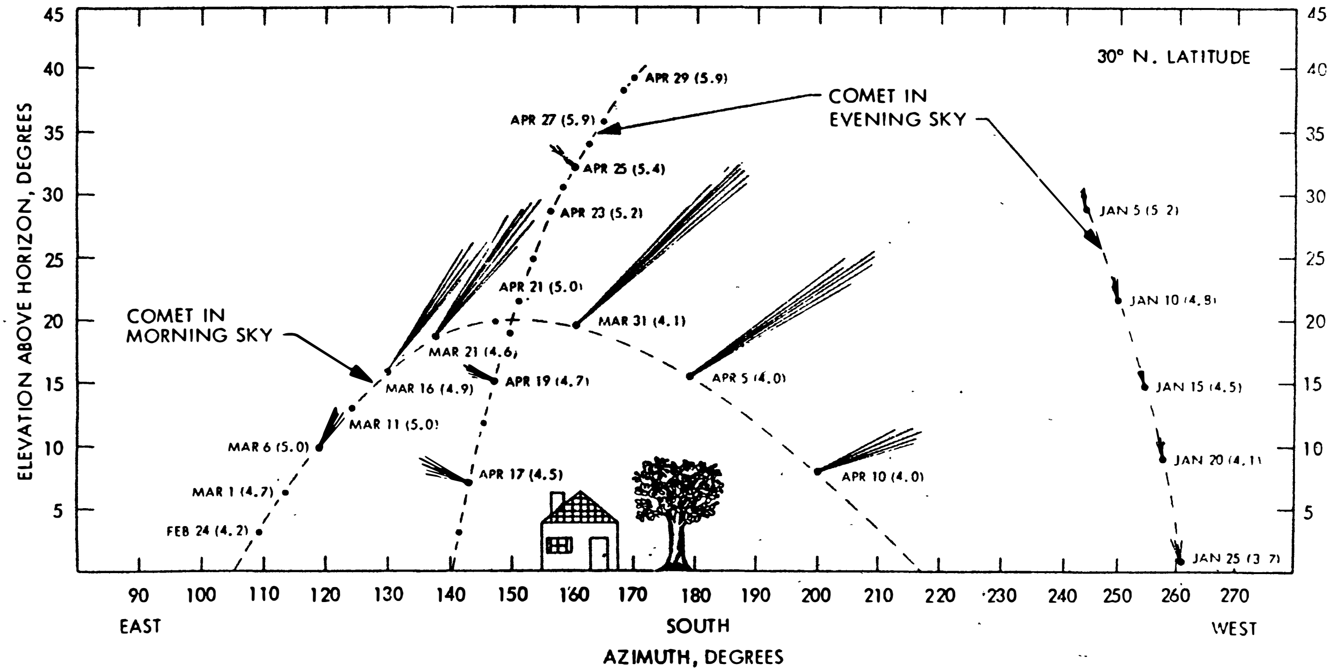
At least two Shuttle missions will study Halley's Comet. In this artist's impression, an orbiter with Spacelab in the cargo bay appears against a sky in which the comet is in southern Lupus between Scorpius and Centaurus. *Don Dixon, copyright Space Frontiers Ltd.*

Until the comet develops a tail (which will probably be poorly seen from the UK) it will look like a small, diffuse or cloudlike ball, more greyish than white. Another important feature is that while the comet will be moving at very high speed in absolute terms, it will move only gradually against the backdrop of stars so it will take the passage of a few hours for this movement to become clearly discernible.

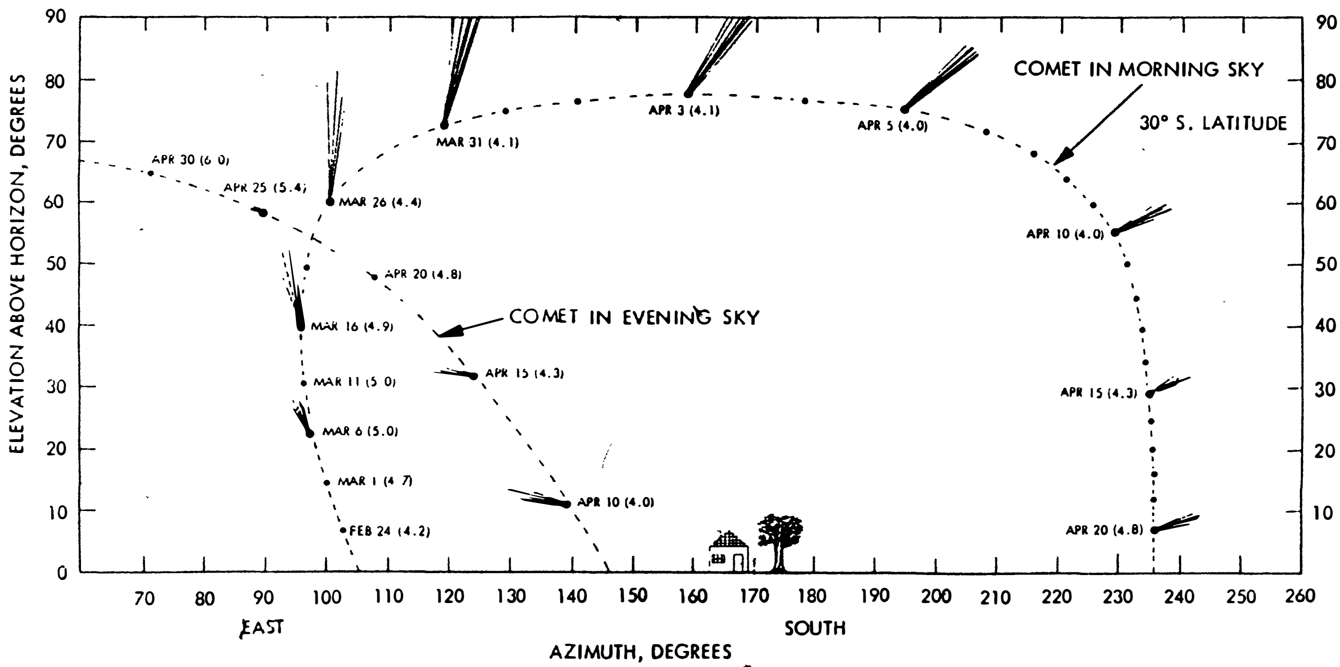
From mid-December until around the middle of January 1986 it will be quite high in the sky: from 40° or so

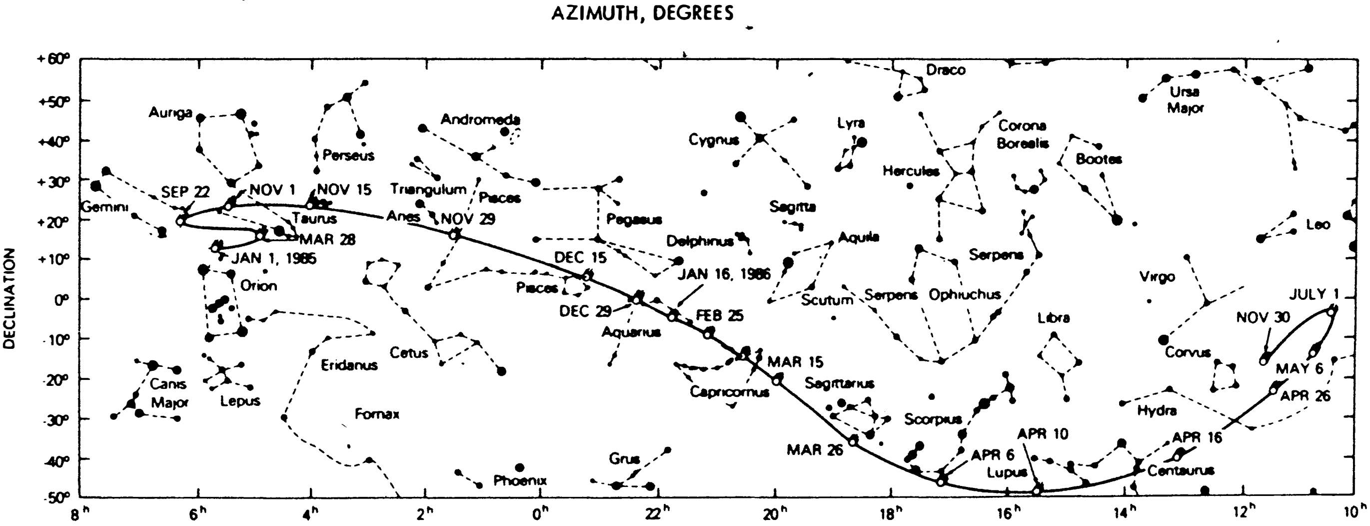
The comet from 50°N - evening twilight. (Figures in parentheses are approximate visual magnitudes).





Observing conditions for 30°S and 30°N in 1986. Comet positions are given for the beginning of morning or end of evening astronomical twilight. Approximate visual magnitudes are given in parentheses following dates. Ideal observing conditions and viewing with binoculars are assumed. *Courtesy IHW*





Comet Halley's Path on the Celestial Sphere: 1985-86.

altitude declining to about 10°. It will be setting about 1 a.m. on December 12, about 11 p.m. on December 20, 8 p.m. on January 6 and about 6.30 p.m. on January 14. The Moon (which reduces our ability to discern diffuse objects) will create problems for naked eye viewing for some days after December 16 (it is new on December 12) but another good viewing 'window' will open after full Moon (on December 27) and on into early January. We, in the UK, will effectively lose Halley's comet in about mid-January.

After perihelion, however, there is another chance to see it from the UK. From toward the end of April and on into May it will again be an evening object, but never higher than about 20° above the horizon. On the other hand, it will not set until around 1.00 a.m. for most of this time and the Moon will be reasonably cooperative too.

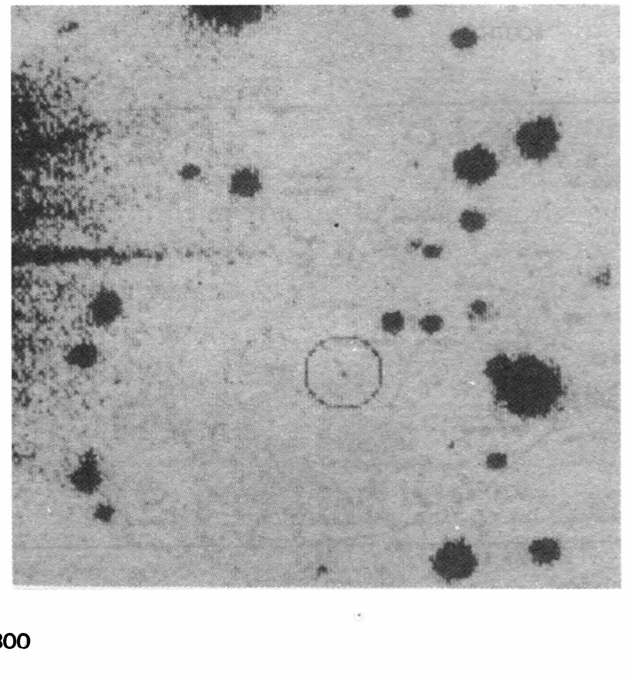
Since the comet will be an evening object for the UK in December 1985-January 1986, and again in the spring, it will be found toward the south initially and then, increasingly, to the west. So try to ensure the darkest possible sky and clear horizon in that direction, though light pollution will be a problem in towns and cities.

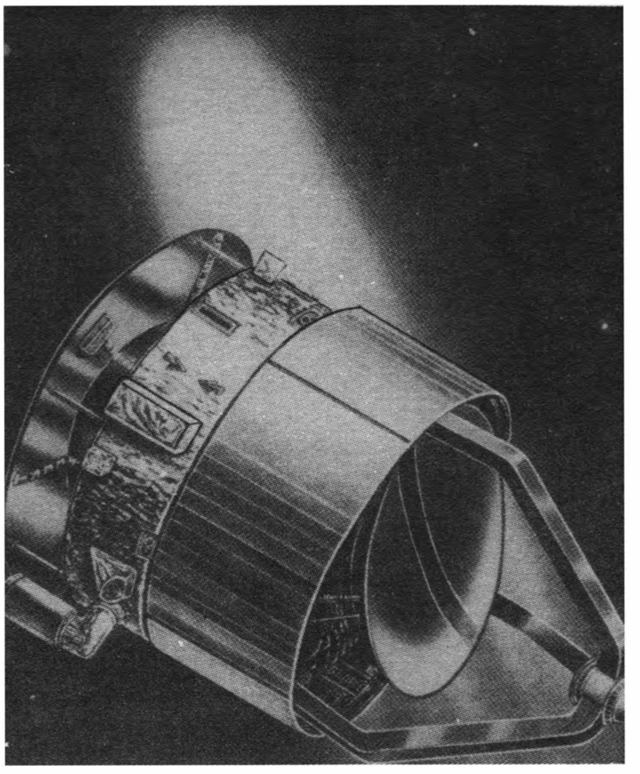
Photographing the Comet

With any comet there is the problem that it moves independently so its motion does not match that of the stars. The experienced comet photographer will be tracking the comet itself during his exposures, although to do this visually is not easy when the target has a fuzzy, diffuse coma. In using a fixed camera on a tripod for a lengthy time exposure it is clear that not only will the stars trail but the comet, too, will move. The fuzzy object will become even fuzzier. For the astrophotographer or the specialist observer engaged in the International Halley Watch this would simply not be good enough but for the ordinary photographer it will be worth-while making the attempt, unless the comet is impossibly dim.

Light pollution is an important factor. If the comet is swamped by a pall of light the film will record that at the same time as it does its best for Halley. It would be wise to conduct some tests in advance once a location for the camera has been chosen. Expose a series of frames of

The image showing Halley's comet (ringed) obtained by astronomers D.C. Jewitt and G.E. Danielson at Mount Palomar, California on October 16 1982. This is the furthest point from the Sun that a comet has ever been observed. *CalTech*





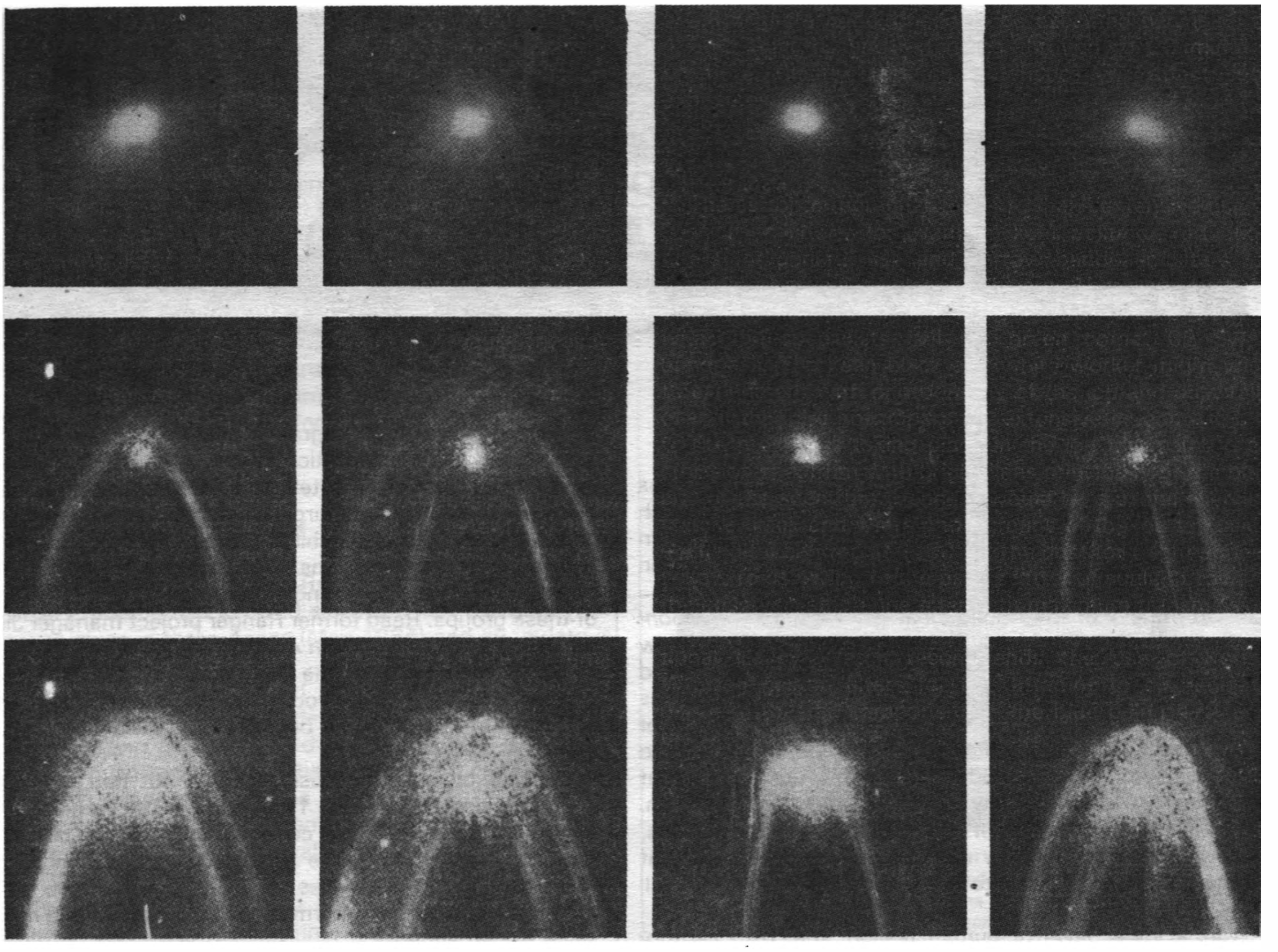
Giotto at encounter with Halley's comet, March 1986. *Space Frontiers Ltd*

the sky area where the comet will be, using the same exposure steps planned for the great night. Various magnitudes of stars will be recorded; and one will be able to see what length of exposure yields a degree of sky fog that overwhelms stars of the middle magnitude to which Halley's comet approximates. In dark skies, even if the comet is dim, there should be adequate contrast in the scene to make the attempt worthwhile - but bear in mind that, even with otherwise good sky conditions, the Moon could create problems.

The camera must have a facility for time exposures. (Many modern cameras may be draining batteries at quite a rate during time exposures - which is why a mechanical release capability is so useful). Use a *lockable* shutter cable release and employ the astrophotographer's 'black card trick.' Take a piece of black card and hold it in front of the lens when the shutter is opened. Wait for several seconds to make sure that all vibrations have ceased and then move the card away - taking care not to touch camera or lens with it!

A further point: quite often a hair drier is an essential part of the astrophotographer's kit. On some nights condensation can be a problem (despite the use of a lens hood) so keep a close watch on the front of the lens. Gentle use of the drier from a discreet distance will normally keep things under control; with care, it could be used during an exposure.

If the comet develops a reasonable tail then the standard 50 mm focal length lens for the 35 mm camera, with its 26 x 38° format will be suitable since a tail can extend easily for 30° or more. This would make for a very attractive picture, particularly if there is an interesting horizon. If, however, we do not see much of a tail from the UK then the size of the comet's head will be very small and focal lengths of at least 200 mm will be needed to secure a moderately-sized image. Shorter focal length lenses can be stopped down from f/1.2 or f/1.4 to f/2.8 to secure best optical performance. With longer focal length lenses f/2.8 may not be available and longer exposure times will need to be adopted.



S. Larson of the Lunar and Planetary Laboratory of the University of Arizona produced this set of computer enhanced images of Halley's comet taken originally by G.W. Ritchey at the Mt. Wilson Observatory during 5th to 8th (from left) May 1910. The original images are at the top.

Films

The 400ISO family of black and white films will probably be the most convenient to use. Astrophotographers will be concentrating on using Kodak Technical Pan Film 2415, which combines fine grain with reasonable speed and 'tunable' contrast if hypersensitised in a vacuum chamber full of a non-flammable forming gas.

As far as colour is concerned, since Halley is likely to be so dim there is a natural tendency to opt for one of the new 1000ISO plus type of transparency films introduced by Fuji, 3M, Kodak and now Agfa. There is one important point to remember: with time exposures of the length likely to be used during the visit of the comet there is every chance, because of reciprocity failure, that one of the high speed colour films will deliver no more effective performance over a given time than a medium speed, higher quality film.

A problem might arise from the fact that the images will be very different from those usually handled by a commercial processor. With transparency films, one should either specify that they be returned uncut or shoot a normal scene as the first exposure of each so that the cutting and mounting operation proceeds safely and does not result in frames neatly cut in two.

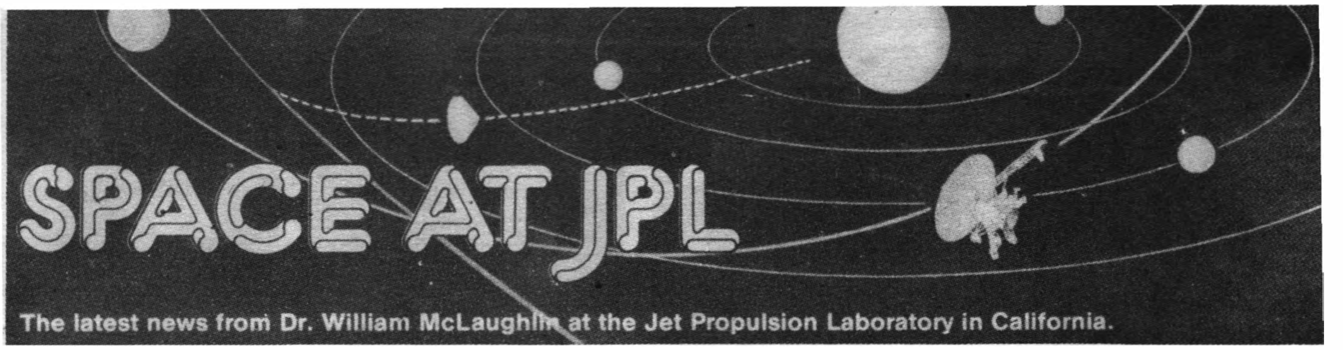
Exposures

If the comet were to surprise us all and become a good naked eye object with a splendid tail then, with fast films at f/2.8, a range of exposures starting from as short as 1/60 sec to 2 or 3 seconds would be possible. The likelihood is that the comet will not oblige, at least for those of us in the UK, so one needs to look at the other end of the time scale. Using medium to high speed colour or black and white films, a programme of exposures at f/2.8 or faster would need to be executed beginning at 1 or 2 minutes and extending through to 20 minutes or more. Clearly, lens characteristics will affect such exposures.

Filters

The astrophotographer tends to make extensive use of specialised filters; for example, light pollution reduction filters for general use and narrow bandpass filters for recording particular celestial objects. There are even so called 'comet' filters that record from 4950-5200 Å - what the specialists call the green comet C2 Swan bandpass. The keen black and white worker might wish to experiment with photography of the ion and dust tails even if they are not apparently extensive in length.

The processes taking place in the ion tail result in an emission spectrum with bright lines principally at the blue end of the spectrum. Hence it would be a useful exercise to take black and white photographs of the ion tail using a blue filter centred at 4400 Å. The dust tail might appear yellow to us owing to the back scatter of sunlight toward the observer; an orange filter with maximum transmission around 6500 Å would enhance this feature. The International Halley Watch recommends the use of Kodak Wratten gelatin filters for this attempt to discriminate between the tail components - the blue being 47A and the orange 21.



LURE OF THE MOON

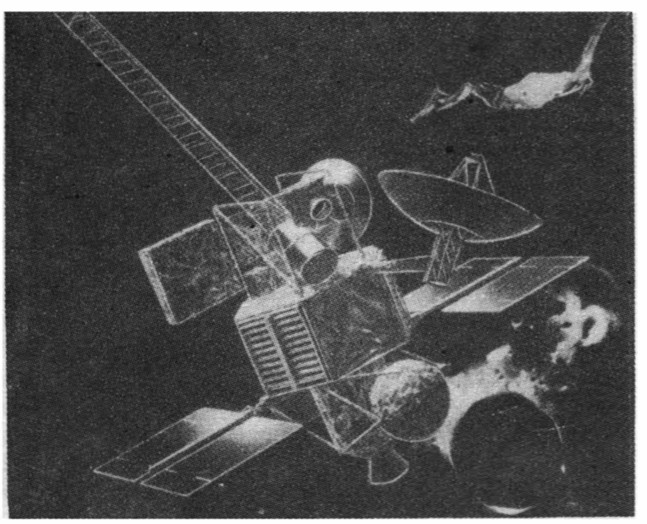
The advanced concept review for this month examines some plans for unmanned lunar exploration. Although NASA has not at present funded a lunar project, return to the Moon remains a popular subject for speculation and study.

On the eve of the Apollo lunar landings, *To the Moon!* (H. and H. Wright and S. Rapport, Meredith Press, New York, 1968) presented a collection of popular, literary and technical views of the Moon. The Apollo 11 landing was later covered by novelist Norman Mailer in his mixture of fact and fancy, *Of a Fire on the Moon.* These two works exemplify the blend of poetry and technology that inevitably accompany any discussion of a lunar mission. Poetry, the sublimator of many of our deeper feelings, has usually done well by the Moon as in Shelley's 'That orbed maiden, with white fire laden/Whom mortals call the Moon.'

At a lower level of human feeling, the 16th century physician Paracelsus held that 'lunacy grows worse in full and new Moon, because the brain is the microcosmic Moon.' Even if we do not accept his explanation, we nevertheless must accept his observation that humans are strongly affected by the lunar cycle. It is easy to ascribe these feelings about the Moon simply in recognisition of its governance over our ancient home, the sea.

Several of my colleagues at JPL are definitely 'friends of Mars'; their eyes light up and the conversation flows more rapidly when the subject of the Red Planet is introduced. Then there is the JPL navy: people with a love of the sea. This group has furnished significant staffing for the oceanographic satellites Seasat and TOPEX. Similarly, exploration of the outer planets, comet missions, astronomical satellites and other genera of our business each have their circle of admirers - perhaps from associations formed in childhood or favourable experiences on former missions. The friends of the Moon, however, are more loyal and true to their object than any of these groups. Read former Ranger project manager Jim Burke's 'Personal Profile' in April 1984 *Spaceflight.* Listen to Neil Armstrong from the lunar surface, 'It has a stark beauty all its own.' Even your correspondent's roots back to Apollo would probably bear life with little encouragement.

In this artist's conception by Paul Hudson, the proposed Lunar Geoscience Orbiter is shown as it collects scientific data from 100 km above the Moon early in the next decade. *NASA/JPL*



Lunar exploration enthusiasts have not had much to celebrate since the Apollo 17 mission in December 1972 when Cernan and Schmitt collected over 100 kg of rocks from Taurus-Littrow in the Sea of Serenity and brought them back to Earth. Studies of lunar materials have been the principal source of information in the decade and more since Apollo ended.

In the last half of the 1970's some JPL studies focused on an unmanned Lunar Polar Orbiter mission (see, for example, Jim Burke's paper on the subject in *Acta Astronautica,* **4,** 907-920, 1977). The idea was to conduct a global survey of the Moon to extend the detailed but more localised knowledge obtained through Ranger, Surveyor, Lunar Orbiter and Apollo. No funded mission grew out of this activity but it has laid the basis for some current ideas for lunar exploration.

The Lunar Geoscience Observer (LGO) is a study underway at JPL. It falls in the Planetary Observer series (see the May 1984 edition of this column) which includes the Mars Observer project (funded and scheduled for a 1990 launch), the proposed Near Earth Asteroid Rendezvous mission and the proposed Mars Aeronomy Orbiter. The latter two missions will be discussed in this column in the near future.

The objectives of LGO are: (1) measurements of global elemental and mineralogical surface composition, (2) assessment of global resources, including a search for frozen volatiles at the poles, (3) measurement of the global figure and surface topography, and (4) measurement of lunar gravity and magnetic fields. These objects are, in effect, a Landsat-type manifesto for the Moon. They will serve well the geologist, the lunar theorist who seeks the origin of the Moon, the economic planner of future lunar bases and the astronomer who hopes to find a cold lunar crater with ice in order to locate a huge infrared telescope of the future.

One LGO mission scenario would place a single spacecraft in a low (100 km) polar orbit for a one-year survey of the surface. Circling the Moon every 118 minutes, the solar-powered spacecraft would depend upon strong inheritance from the Mars Observer spacecraft. Data would be gathered by nadir-pointed science payload and

returned to Earth at a maximum rate of 32 kilobits per second. This information flow could be collected by small 34 m antennae of the Deep Space Network.

The nominal payload would probably include a gamma ray spectrometer, a visual and infrared mapping spectrometer and a radar altimeter. Enhancements to the payload might add a solid state imaging system, a magnetometer and an electron reflectometer (derived from the Apollo 16 subsatellite charged-particle instrument). No scan platform, such as Voyager and Galileo carry, would be provided for the remote sensing instruments; they would be hard mounted and boresighted in the nadir direction. Any pointing away from the nadir would have to be implemented within the instrument.

Thanks are extended to James Randolph, who manages Planetary Observer at JPL, for providing information concerning LGO.

RENDEZVOUS WITH COMET WILD 2

The proposed Comet Rendezvous/Asteroid Flyby (CRAF) mission has evolved since the last description of it was given in these pages (May 1984) and an update is in order.

The CRAF mission would be the first of the Mariner Mark II series which JPL is designing to explore the outer Solar System and small bodies (comets and asteroids), using proven technology. The mission is a candidate for a new project start in the fiscal year 1987 budget, which covers the period from October 1986 through to September 1987. If approval is obtained then, a launch in 1991 is planned.

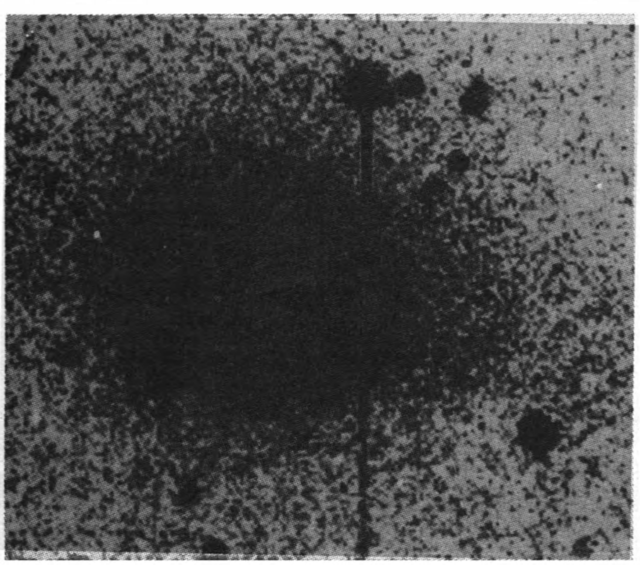
The nominal launch date is 10 March 1991 when a Shuttle with a Centaur G-prime upper stage would place the 2400 kg spacecraft on an Earth-escape trajectory. On 23 September 1991 the spacecraft would flyby asteroid Hedwig to within 6,000 km to 10,000 km and conduct a programme of scientific investigations. Hedwig, with a diameter of just over 100 km, is somewhat smaller than the 200 km asteroid Amphitrite that Galileo may flyby in December 1986 on its way to Jupiter.

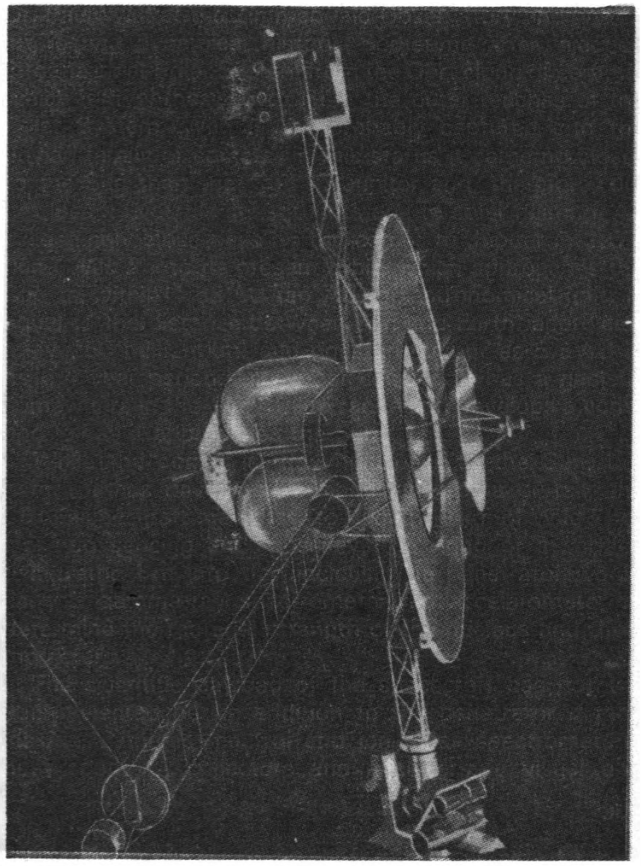
Rendezvous with Comet Wild 2 is planned to take place on 8 January 1995. Wild 2, which replaces Comet Kopff as CRAF's target, was discovered on 6 January 1978 by Dr. Paul Wild at the Zimmerwald Observatory and has an interesting dynamical history. Sometime after injection into the inner Solar System from the Oort cloud of comets, which is hypothesised to lie in the outer reaches of the Solar System, Wild 2 was probably captured into the Jovian family of comets. In this status it came no closer to the Sun than the orbit of Jupiter and, therefore, did not lose its volatile constituents due to solar heating. An exceedingly close pass by the comet to Jupiter in 1974 flung Wild 2 into its present orbit, which approaches the Sun to within 1.58 AU (an AU, or astronomical unit, is equal to the distance between Sun and Earth: approximately 150 million km) and goes as far out as 5.3 AU in its 6.4 year period. Like most comets, it has a nucleus somewhere in the 1 to 10 km range and develops a coma and tail as it approaches the Sun.

While the comet is drawing closer to the Sun, but before it has developed a significant coma or tail, the CRAF spacecraft may draw to within 10 km of Wild 2 for close-up sensing and, possibly, the firing of a surface penetrator 1 m into the nucleus. The penetrator would carry a gamma-ray spectrometer, an accelerometer to determine the material strength of the nucleus and thermometers.

The scientific payload of the spacecraft has not yet been selected but in addition to the penetrator it may include: cameras; neutral and ion mass spectrometers; dust counters, collectors and analyzers; a visual and

This image of periodic comet Wild 2 was taken by Michael J.S. Belton (Kitt Peak National Observatory) and P. Wehinger (Arizona State University) on 4 January 1984, using the 4 m reflector at Kitt Peak. Taken while the comet was at a distance of approximately 2.6 AU, it shows the coma but no appreciable tail is visible. Wild 2 has been selected as the rendezvous target for the first of the proposed Mariner Mark II mission. KPNO





The Mariner Mark II spacecraft that may be used to approach Comet Wild 2 is depicted by artist Ken Hodges. The circular ring surrounding the high-gain antenna supports the solar panels (power will also be supplied by RTGs). The long boom in the foreground contains a magnetometer. Mounted on the boom (appearing) nearest to the magnetometer is the scan platform with its remote sensing instruments, while the fields and particles instruments inhabit the third boom. Compare with an earlier version of the CRAF spacecraft design illustrated on p.115 of the March 1984 *Spaceflight*. NASA/JPL

infrared mapping spectrometer; and a magnetometer.

Before cometary activity becomes dangerous, the spacecraft would pull back from the nucleus to a distance of several thousand kilometres, but maintain rendezvous in order to study the physical and chemical processes as the Sun is approached. Closest approach of Wild 2 to the Sun takes place on 7 May 1997. The CRAF mission would continue until 30 September 1997, when almost three years of rendezvous and study would have been completed.

FY 1986 NASA BUDGET

President Reagan proposed a budget for NASA totalling $7,886 million for Fiscal Year 1986.

Included in this amount was $1,613 million for space science and applications, of which $359 million was proposed for planetary exploration and $630 million for physics and astronomy.

The largest line item under planetary exploration was the $112 million for the Venus Radar Mapper mission. The Mars Observer mission was allocated $43.8 million, with $39.7 million scheduled for Galileo and $5.6 million for Ulysses. Mission operations and data analysis for ongoing missions (JPL's Voyagers, Galileo after launch and the Pioneers of the Ames Research Center, for example) received $95 million. The remainder of the planetary exploration budget ($62.9 million) will be employed in research and analysis.

The planetary programme received no new project starts for FY86; the previous fiscal year saw the start up of the Mars Observer project.

TRAINING FOR URANUS

The Laboratory's approved planetary missions have been discussed frequently in these pages: Voyager (Uranus, 1986), Galileo (Jupiter, 1988), Venus Radar Mapper (1988) and Mars Observer (1991). The year indicated in this list corresponds to the encounter with the relevant planet and is as important as the planet itself for characterising the current status of the project.

The Venus Radar Mapper (VRM) and Mars Observer projects are still developing their respective spacecraft and missions, with VRM quite naturally in advance of the Mars Observer. The hardware for Galileo is completed and its mission operations sytem is being put in place. Voyager, which conducts its programme of scientific observations of Uranus from 4 November of this year to 25 February 1986, is being readied with computer sequences to accomplish this observing programme and the flight team is training for the encounter.

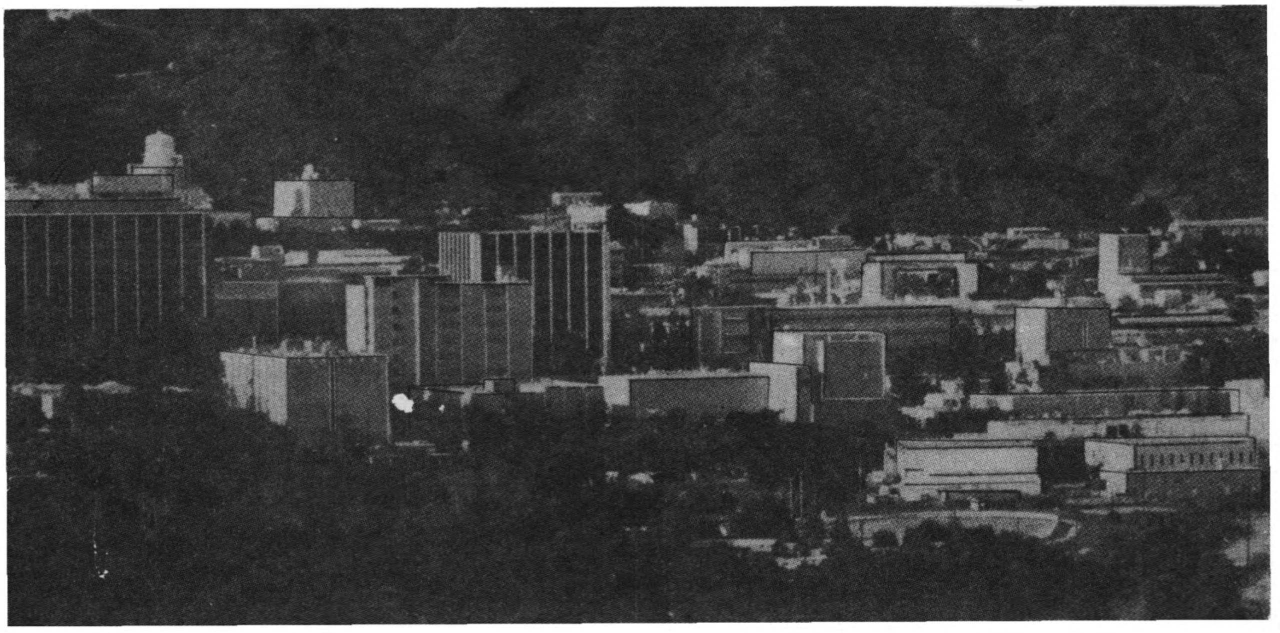
At encounter with Uranus there will be somewhat over 200 members of the flight team (plus scientific investigators who are resident during part of the encounter period). Their relationships to one another, to other elements of the ground system and to the spacecraft are numerous and complex.

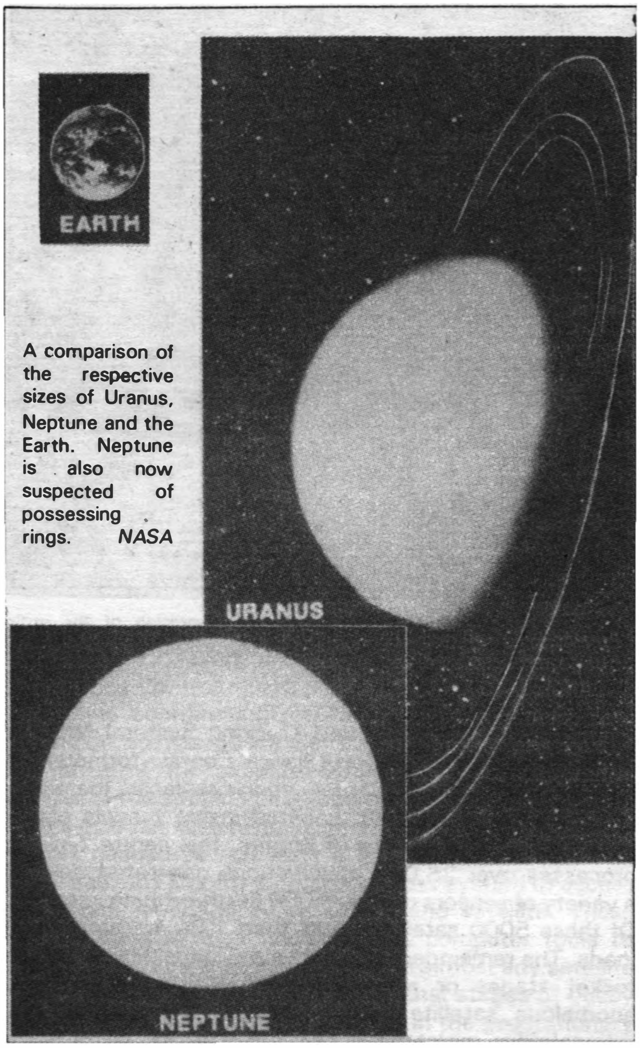
The first order of business is to ensure that the various documents describing encounter operations procedures and interfaces are correct and have been properly revised since the last Voyager planetary encounter (Saturn in 1981).

One procedure of particular interest is that associated with the issuance of a real-time command from the ground to the spacecraft. Three types of instructions reside in the primary controlling computer of the spacecraft (this computer is called the Computer Command Subsystem, or CCS). The first type has more-or-less permanent residence and constitutes the operating system of the computer. The second type of instruction resides in which is called a 'sequence': a block of instructions sent up as a unit every few weeks (more often when very close to Uranus) for the purpose of carrying out the observing programme until the instructions are used up and another sequence is sent from the ground (nine of these sequences will cover the November-February encounter). The third type of instruction results from a real-time command and most often is used to modify the ongoing sequence.

Real-time commands inherently carry more risk than does the transmission of a whole sequence block. This is because the sequence is developed over a longer time than the real-time command and consequently is subjected to more reviews by more people. Also, computer simulation (by ground computers) is more extensive for the sequence.

The Jet Propulsion Laboratory, from where Voyager 2 is being controlled for its Uranus and Neptune flybys.





A comparison of the respective sizes of Uranus, Neptune and the Earth. Neptune is also now suspected of possessing rings. *NASA*

The risk of making a mistake in issuing a real-time command (perhaps by sending a faulty command or one that has an unexpected effect) drives the project to restudy the process from time to time, and this Spring such an effort has been undertaken to improve existing command procedures. Improvements range from making corroborative computer printouts easier to read to introducing additional review before transmission of the command. In this way the five or ten real-time commands usually required each week stand in even higher chance than before of being without blemish.

After review of procedures the actual training of the flight team begins in August, with intrateam training featured. There are functionally-determined teams on Voyager: Mission Control (Team), Spacecraft, Navigation, Sequence, Science Investigations Support, Data Management and several others. Intrateam training consists of a variety of activities such as review of the written team operating plan and procedures by each member of the team, viewing of previously prepared videotaped lectures and participation in training classes.

In addition to these individual activities the various teams will practise some of their more difficult and important tasks as a unit. For example, the Navigation Team will rehearse 'TCM tweaks.' A 'TCM' is a trajectory correction manoeuvre and a 'tweak' is a last minute improvement of the manoeuvre parameters based upon the latest tracking data. There are three TCMs during the Uranus encounter period and each will have its associated tweak. Two TCMs occur before the closest approach to the planet (about 30 days and 5 days) and are intended to place Voyager 2 precisely on its planned trajectory. The third occurs shortly after closest approach and adjusts the trajectory for the encounter with Neptune in 1989. Incorporation of the very latest data is important for these TCM tweaks, hence they are delayed until a day or two before the manoeuvre and must be performed quickly and correctly. This can be assured only if the requisite analysis and computer runs are rehearsed until they are smooth and certain.

The scope of test and training widens in September and October with the introduction of interteam training, which involves two or more teams. The training period will include approximately four major tests, each of which can last from several days to two weeks.

One planned test involves the modification of a sequence to accommodate the hypothetical malfunction of a gear that drives the scan platform on which are located the remote sensing instruments of Voyager 2, including the cameras. This type of malfunction actually occurred on Voyager 2 shortly after closest approach to Saturn (see the February 1984 'Space at JPL'). Although extensive analysis of the fault has shown that, with high confidence, the scan platform should function properly with careful use (no use of high-rate slews, only very limited use of medium-rate slews and most reliance placed on low-rate slews) there is still a possibility of the gear mechanism sticking again. The sequence that spans the closest approach to Uranus is the scientifically most valuable sequence and will be backed by a roll sequence 'on the shelf.' That is, if the gear should stick, an alternative sequence will be ready and can be quickly radioed up to the spacecraft. This alternative (roll) sequence would substitute motion of the whole spacecraft about its roll axis for motion of the stuck scan platform. However, it is not an efficient deployment of resources to backup the entire four-month encounter period with these roll-type sequences, so the Sequence Team and the Spacecraft Team will rehearse the process of converting a normal sequence to one that functions with a stuck scan platform.

As described in the March 1984 edition, the spacecraft will pass very close to the satellite Miranda to accomplish, among other tasks, high resolution imaging of its surface. The closeness of the approach (29,000 km), coupled with uncertainties in the position and velocity of the spacecraft and satellite, make it necessary to update the pointing of the cameras just before the time of closest approach. Tracking data (radiometric and onboard optical) will be accumulated until about 40 hours before the observing period. These data must be quickly delivered to the Navigation Team for approximately 10 hours of processing to obtain a new and more accurate trajectory which is then used by the Spacecraft and Sequence Teams (together they have about 18 hours) to update the scan platform pointing instructions in the sequence. Finally, the updated sequence, in the form of a computer file, is delivered to the Deep Space Network for uplinking to the spacecraft. The latter process must be allotted several hours and always involves some risks, not only because station problems are possible but also because Voyager 2 has had a balky radio receiver since 1978 and sometimes experiences difficulty in accepting commands from the ground.

The 'Miranda late update' described above is clearly an activity that requires practice. The affected elements of the flight team will rehearse the process at least twice during interteam test and training, with a third test possible if rough edges remain.

Beginning on 4 November, the Voyager flight team will put all this practice to use as the encounter with 'the Jolly Green Giant,' mysterious Uranus, starts to unfold.

THE NORAD SPACE NETWORK

By G.T. DeVere and N.L. Johnson

Satellite tracking is one of the more mundane aspects of the Space Age but it is also one of the most important. The NORAD (North American Aerospace Defense Command) system in the US maintains a catalogue of more than 5000 objects at any one time, of which only 5% are active satellites. The authors describe the purpose of the system and how it operates.

Introduction

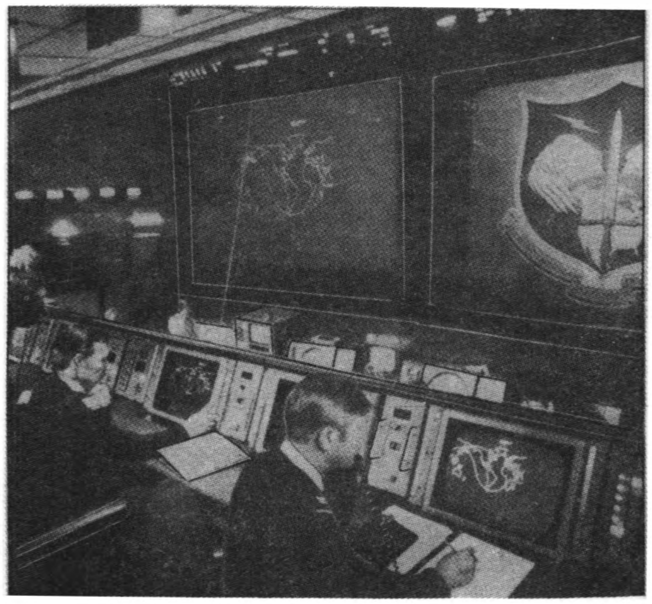
When the $100 million Tracking and Data Relay Satellite was temporarily lost following a malfunction of its Inertial Upper Stage in April 1983, a team of dedicated satellite trackers quickly responded to an urgent cry for help from NASA. While spacecraft and booster controllers were still receiving fragmentary data from their vehicles, the NORAD Space Sensor Network, which had observed the actual motor firing *via* one of its Ground-based Electro-Optical Deep Space Surveillance sensors, continued to provide NASA with up-to-the minute orbital data on the wayward satellite. With NORAD's help, NASA not only rescued the expensive spacecraft but also nursed it into the proper geostationary orbit over a period of many weeks.

The North American Aerospace Defense Command's (NORAD) mission of maintaining positional data on Man-made objects in space involves many different segments. From the nerve centre within the Cheyenne Mountain Complex near Colorado Springs in Colorado with distant sensors in such remote locations as Thule, Greenland and Ascension Island in the Atlantic, NORAD's mission is to monitor artificial Earth satellites daily. This includes objects ranging from old inactive payloads such as Vanguard 1, launched in 1958, to the most recent Shuttle mission.

The NORAD System

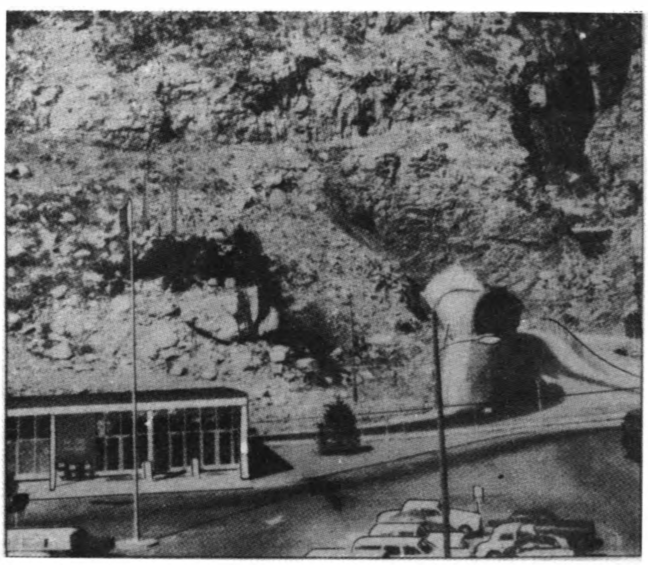
The heart of the NORAD Space Sensor (formerly SPADATS, Space Detection and Tracking System) Network is the NORAD Space Surveillance Center, formerly the Space Computational Center, which replaced the Space Defense Center in 1979. Located inside tunnels carved out of millions of tonnes of granite, this centre typically processes over 25,000 observations generated daily by a variety of sensors on over 5000 Earth-orbiting satellites. Of these 5000 satellites, less than 10% are active payloads. The remainder are inactive payloads, spent booster rocket stages or miscellaneous debris resulting from anomalous satellite events, such as explosions. The rationale for maintaining the positions of all of these objects is several fold. First, by keeping track of objects currently in orbit, detection of newly-launched objects is facilitated. The maintainance of satellite positions is also necessary to plan space launches and orbital manoeuvres in order to prevent possible collisions and to assess foreign rocket satellite operations. NORAD also predicts where satellites will reenter the atmosphere.

These reasons provide the motivation for the crew of seven to ten highly trained US Air Force personnel on duty 24 hours a day, seven days a week in the NORAD

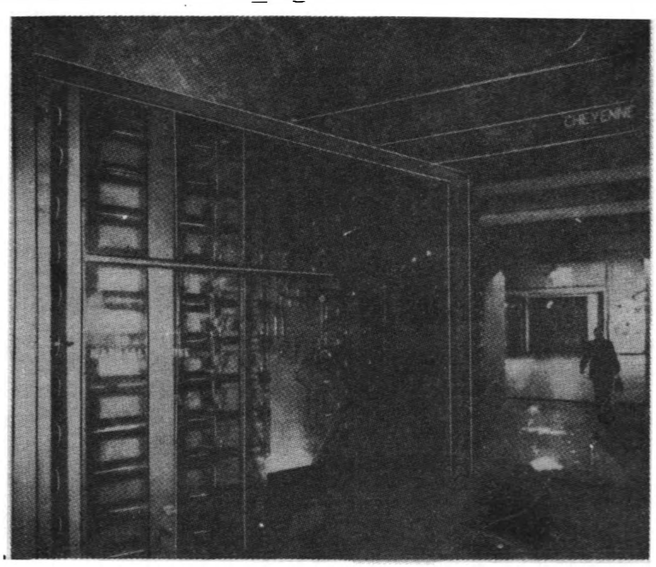


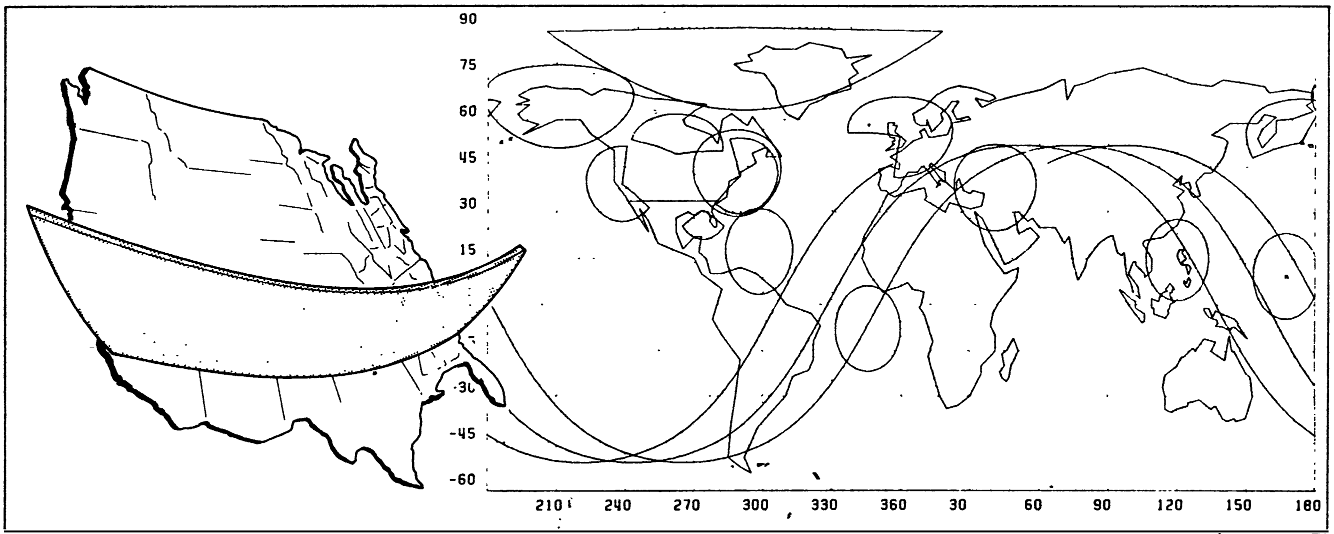
The NORAD Command Post controls the operation of the entire Cheyenne Mountain Complex.

The entrance to the long tunnel leading to the Cheyenne Mountain Complex is 2000 m above sea level.



Two 25 tonne steel blast doors protect the personnel inside; they can be closed in less than 30 seconds.





Left: The Naval Space Surveillance System creates a radar fence across the US at approximately 33°N latitude. *Right:* the first three orbital revolutions of a Soyuz T spacecraft with the corresponding coverages of the primary space sensors.

Space Surveillance Center. These individuals, working as a cohesive unit, work under the direction of the Space Surveillance Controller. His job is to supervise his crew in addition to coordinating real-time tasks for the sensors that make up the Space Sensor Network. He monitors the status of the satellite catalogue and responds to changes in the satellite population, such as new launches, decays or other activities. To provide the highly technical support needed to run such a vast system, a team of orbital analysts employ a huge computer system to access information regarding every sensor and satellite. These analysts have at their fingertips the computer tools to provide comprehensive information on almost any satellite orbit, whether it is a satellite in the final stages of decay or an active communications satellite in the geostationary belt relaying telephone conversations across the world. These individuals form the nucleus around which the NORAD Space Sensor Network operates.

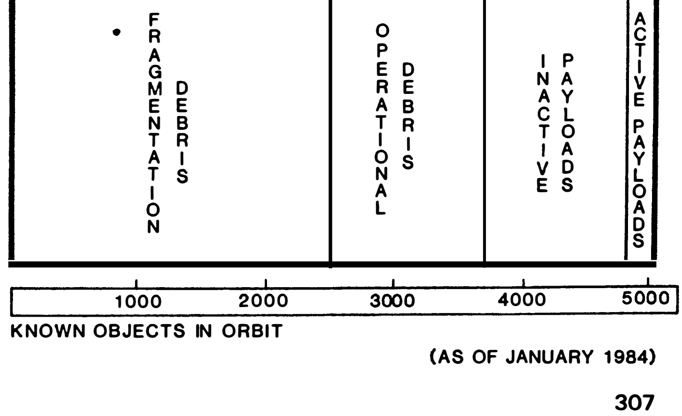
These officers are called upon daily to perform complex calculations; for example, the exact determination of where a satellite in the final stages of decay will reenter the atmosphere. They direct the sensor resources to search for newly-launched Soviet and Chinese satellites, as well as those launched by the United States and other organisations. This flexibility was demonstrated after the anomalous deployments of the Westar 6 and Palapa B2 communications satellites from the Shuttle in February 1984. Within a few hours of the engine malfunctions, the NORAD Space Surveillance Center had generated orbital element sets not only on the two valuable payloads but also the resulting pieces of debris. From these data, NASA was able to assess the propulsion failures and to generate new mission plans.

However, the work done within the Center would not be possible were it not for the contributions of the far-flung tracking sites. Some sensors are the traditional mechanically-driven, dish-shaped, tracking antennae. Others use the more sophisticated, all-electronic phased-array technology. Still others are of the optical or electro-optical variety. In all, there are 20 primary sensors contributing to the Space Sensor system, some of which are more than 20 years old, while others have only recently been completed.

One of the systems is the Ballistic Missile Early Warning System (BMEWS), based at three sites: BMEWS site 1 at Thule, Greenland; BMEWS site 2 at Clear, Alaska and BMEWS site 3 at Fylingdales, England, all built in the early 1960's. All currently employ mechanical tracking radars for observing satellites; however, plans are underway to upgrade two to the more modern and sophisticated phased-array type. The Thule radar is to be replaced by a phased-array radar built by Raytheon to provide more accurate and timely information. Construction is already underway and should be completed by 1987. The other upgrade, now in the initial planning stages, could replace the three Fylingdales mechanical tracking radars with an ultra-sophisticated three sided phased-array radar. This would greatly enhance the ability to provide more accurate satellite tracking data.

Another group of sensors are the Sea-Launched Ballistic Missile warning radars. This network currently consists of four sensors, all of which provide some support to the satellite tracking missions. These radars are of the phased-array variety and consequently are able to track many objects simultaneously. This proves to be of a great benefit when supporting the tracking of satellites since mechanical dish radars can typically track only one object at a time. The initial configuration of six dish radars (located in Maine, Florida, North Carolina, Oregon and two in California) has evolved into a more capable system and additional upgrades are planned. Currently there are two radars of the new 'Pave Paws' variety located in Massachusetts and California, Pave Paws East and Pave Paws West respectively. These highly complex, two-faced radars cover 240° in azimuth and provide coverage over both east and west United States coastal areas. Two more of this type are planned to be active by 1990: one in Georgia (Pave Paws Southeast) and the other in Texas

Only 5% of all tracked satellites are operational spacecraft.



(Pave Paws Southwest). In addition to those currently operational, there are two other phased-array radars that contribute to satellite tracking. One of these is located in Florida near the northern shores of the Gulf of Mexico at Eglin Air Force Base. This sensor was originally built to perform only satellite tracking but was modified in 1973 for other purposes. The other is located in North Dakota and was originally designed to be part of the Anti-Ballistic Missile programme. When this was cancelled, the radar, which was already completed, became a part of NORAD. Both are major contributors to the network, together transmitting of one third of the satellite observations received daily at the Space Surveillance Center.

There is another large phased-array radar, code-named Cobra Dane, on Shemya in the Aleutian Island chain off the coast of Alaska. Several dish radars built to support different test programmes are now also used for the Space Sensor support; these include the radars on Antigua and Ascension Islands in the Atlantic and one on Kwajelein Atoll in the Pacific.

There are two other dish-type radars used to support the satellite tracking mission; one is in Pirinclik, Turkey (the site was formerly called Diyarbakir) an the other is found on the Phillipines in the Pacific. They provide timely information on new Soviet and Chinese launches because of their proximity to the Asian landmass. The radars on Kwajelein and Phillipines make up two thirds of the Pacific Radar Barrier; the third, planned for an island near Guam, should be active by 1990. These three radars will be able to detect almost any easterly launched Soviet or Chinese spacecraft on the satellite's first orbital revolution.

A unique sensor system and one that plays a vital NORAD role is the Naval Space Surveillance System. This very high frequency system erects an electronic fence across the southern United States (latitude 33°) that can detect almost any satellite overlying the continental US. The system consists of one main transmitter at Lake Kickapoo, Texas; two auxillary transmitters at Gila River, Arizona and Jordan Lake, Alabama; and six receivers at San Diego, California; Elephant Butte, New Mexico; Silver Lake, Mississippi; Fort Stewart, Georgia; Red River, Arkansas and Hawkinsville, Georgia. Owing to its fine discrimination ability, this system is a primary tool for characterising and evaluating satellite break-ups.

In addition to the radar sensors, NORAD has several optical and electro-optical sensors available to track satellites routinely. Because of basic radar range limitations, some high satellites are not detectable by most conventional radars. Their tracking often requires optional techniques. Two systems are currently employed by NORAD: the older Baker-Nunn cameras and the new Ground-based Electro-Optical Deep Space Surveillance system (GEODSS). The Baker-Nunn cameras, telescopically mounted and first deployed in 1957, are being phased out in favour of GEODSS. Whereas Baker-Nunn suffer long delays between observation and data transmission to NORAD, GEODSS sites can actually view satellites in real-time and can provide data to the Space Sensor Network immediately. Eventually, GEODSS sites will be deployed in Portugal and Diego Garcia in the Indian Ocean, in addition to the existing sites at White Sands, New Mexico; Taegu, Korea; and on Maui, Hawaii. This five sensor network of GEODSS, when active in 1988, will provide complete coverage of the entire geostationary satellite population.

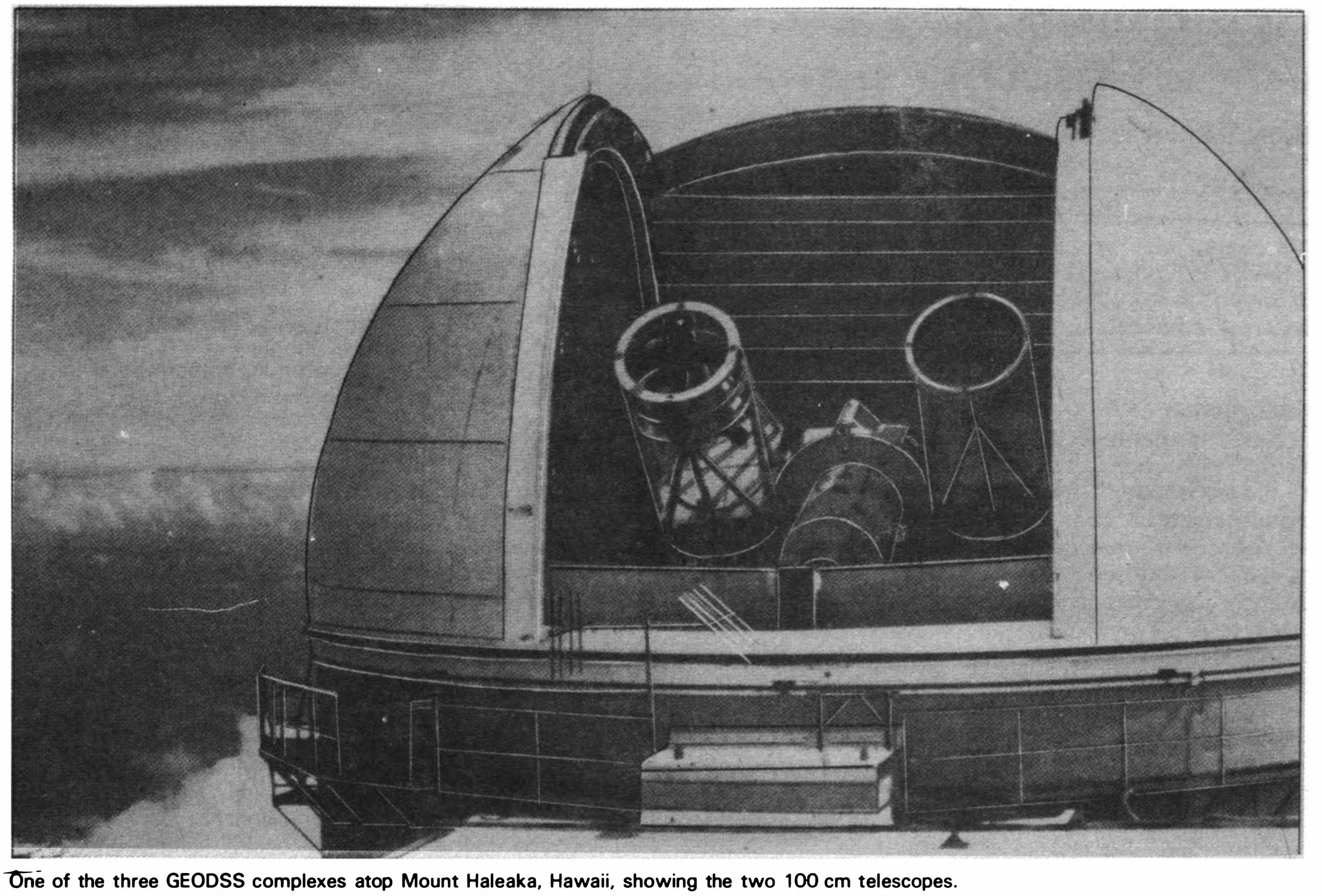
How it Works

An interesting overview of how this network of men, computers and sensors strewn throughout the world functions can be provided by the example of a newly launched Soviet satellite. The Space Surveillance Controller, continually monitoring the status of the Space Sensor system, receives notification of the lift-off of a rocket from the Tyuratam launch complex in the Soviet Union. He then attempts to determine which sensor might be the first to observe the new satellite in orbit. In this case, it appears as though either a manned Soyuz T or a Progress resupply spacecraft was launched. Because of the 51.6° orbital inclination and 88.8 minute orbital period of these satellites, the first sensor that should observe this new object is the Pacific Radar Barrier site on Kwajalein Atoll in the Pacific. This may be seen in the diagram, which shows the first three orbital revolutions of this satellite, along with the coverages of the various sensors addressed earlier. The new Soviet spacecraft and the upper stage body that propelled it into orbit will be tracked by the Kwajalein radar and the observations will be formatted on-site for transmission. As a result of the normal Soyuz booster (A-2) separation sequence, the upper stage of the launch vehicle will be in a lower orbit than the payload and consequently will arrive slightly ahead of the spacecraft.

Following the formatting process, the data are transmitted to the NORAD Space Surveillance Center at the Cheyenne Mountain Complex *via* a high speed communications link. When the observations are received at the centre, the orbital analysts on duty attempt to generate an initial estimate of the satellites' (payload and booster) orbital parameters. This representation of a

Table 1. Current NORAD Space Sensors.

Name	Location	Operating Frequency	Primary Mission(s)
Dish Radars			
ALTAIR (PACBAR I)	Kwajalein Island, Pacific Ocean	415-440 MHz	Satellite Tracking
AN/FPQ-14	Antigua Island,	5400-5900 MHz	Launch Support; Satellite Tracking
AN/FPQ-15	Ascension Island, Atlantic Ocean	5450-5900 MHz	Launch Support; Satellite Tracking
BMEWS Site I	Thule, Greenland	400-450 MHz	Missile Warning
BMEWS Site II	Clear, Alaska	400-450 MHz	Missile Warning
BMEWS Site III	Fylingdales, England	400-450 MHz	Missile Warning
GPS-10 (PACBAR II)	San Miguel, Phillipines	442 MHz	Satellite Tracking
Millstone	Westford, Massachusetts	1295 MHz	Satellite Tracking
AN/FPS-79	Pirinclik, Turkey	432 MHz	Missile Test Monitoring; Satellite Tracking
Phased Array Radars			
COBRA DANE	Shemya Island, Alaska	1175-1375 MHz	Missile Test Monitoring; Satellite Tracking
AN/FPS-85	Eglin Air Force Base, Florida	437-447 MHz	Sea Launched Ballistic Missile Warning; Satellite Tracking
PARCS	Cavalier, North Dakota	420-450 MHz	Missile Warning; Satellite Tracking
PAVE PAWS East	Otis Air Force Base, Massachusetts	420-450 MHz	Sea Launched Ballistic Missile Warning
PAVE PAWS West	Beale Air Force Base, California	420-450 MHz	Sea Launched Ballistic Missile Warning
		EQUIPMENT	
Electro-Optical			
GEODSS-1	White Sands, New Mexico		
GEODSS-2	Taegu, South Korea	2 -40' telescopes 1 - 15' telescope 1-14' telescope	Each connected to an electro-optical system
GEODSS-3	Maui, Hawaii		
Optical			
San Vito Baker-Nunn	San Vito, Italy	Each site has one Super Schmidt Folded Optics Camera, F1.0, focal length of 20"	
St. Margarets Baker-Nunn	St. Margarets Canada		
Radar Fence			
NAVSPASUR	Dahlgren, Virginia (Headquarters)	Radar fence at 33° latitude across United States; 3 transmitters, 6 receivers	



One of the three GEODSS complexes atop Mount Haleaka, Hawaii, showing the two 100 cm telescopes.

satellite's orbital parameters (an orbital element set) is composed of a variety of terms: the orbital period of the satellite, the eccentricity of its orbit, the orbit inclination, as well as other parameters that provide information on where the satellite can be found.

If the efforts of the orbital analysts produce a good orbital element set, the new data are entered into the NORAD data base while the crew inside Cheyenne Mountain awaits the next sensor acquisition. In this case, the radar tracker on Ascension Island should be the next to acquire the spacecraft. Upon completion of tracking the object, Ascension will format the observational data for transmission and send it to the Center. Using the data from both Kwajalein and Ascension, the orbital analysts then attempt to refine the quality of the orbital element sets on both the spacecraft and its booster rocket. If this refining process, which involves highly complex differential corrections of the various orbital elements, is successful, the refined data are again entered into the NORAD data base. They are also transmitted to other interested agencies, including the other sensors in the Space Sensor Network.

The sensors use the new orbital element set to locate and acquire additional data on the new object. In this example, the next several sensors following Ascension would be Pirinclik, Turkey; Kwajalein (again); Pirinclik (again), the Phillipines tracking radar and the Fylingdales tracking radars. As each sensor observes and provides data to the Center, the orbit will be further refined. A new orbital element set is usually transmitted only when the older element set is of insufficient quality to provide a reasonable representation of the actual orbit. This can either be the result of natural orbital decay or a spacecraft manoeuvre. Following some time in orbit, typically 24 hours for the Soyuz T or 48 hours for the Progress, the spacecraft will attempt to dock with an orbiting Salyut space station. Because of differences in the orbits of the two closing objects, some orbit changes will be needed.

Typically the Soyuz T or Progress will manoeuvre to match the orbit of Salyut. Since these spacecraft are continually monitored by the crews on duty in the Center, any change from the expected parameters will be noted immediately. The orbit alteration will be confirmed by other NORAD sensors and a new element set will be generated by the orbital analysts. Following the docking of the two vehicles, further updates will be forthcoming from the Center.

We often take for granted the enormous task of maintaining a watch on the positions of over 5000 Earth-orbiting satellites. Occasionally we ought to thank the unsung watchers in the depths of Cheyenne Mountain and at the tracking sites scattered around the world.

Table 2. Planned Sensor Upgrades and Additions.

Name	Location	Operational Date	Remarks
Phased Array Radars			
Thule Upgrade	Thule, Greenland	1986	Replace Dish Tracker with PAVE PAWS type Phased Array
Fylingdales Upgrade	Fylingdales, England	1990	Replaces Dish Tracker with 3 Faced PAVE PAWS Type Phased Array
PAVE PAWS Southeast	Robins AFB, Georgia	1987	New Phased Arrays to Fill Gaps in Coverage of Southern Sea Launched Ballistic Missile Patrol Areas
PAVE PAWS Southwest	Central Texas	1987	
Dish Radar			
PACBAR III	Guam ?	1990	Third Sensor in the Pacific Radar Barrier; Dish Tracker
Electro-Optical			
GEODSS-4	Diego Garcia,	1986	The Complete 5-site GEODSS Network will Provide Full Coverage of the Geostationary Ring
GEODSS-5	Portugal	1987	

DESIGNING A MICRO-SPACECRAFT

By James D. Burke

The present trend of deep-space craft is one of increasing size and mass. The author, working at the Jet Propulsion Laboratory, presents a case for travelling in the *opposite* direction: making spacecraft as small as possible.

Introduction

Systems that must be highly reliable tend to use old technology. When there is strong cost pressure in addition to the demand for dependable performance, the incentive not to try new ideas is still greater - even, in some instances, when the inherent reliability of new techniques is demonstrably superior. Inheritance is enormously valuable in the creation of complex engineering systems because it brings forward the cumulative experience of many minds dealing with real or imagined causes of failure.

The result is that, in each generation of developments, many of our most successful systems look like antiques. One has only to think of telephone and teletype equipment to sense the commotion that occurs when new techniques, intrinsically better on the basis of physical operating principles but lacking long experience, enter a large system composed of proven and trustworthy elements.

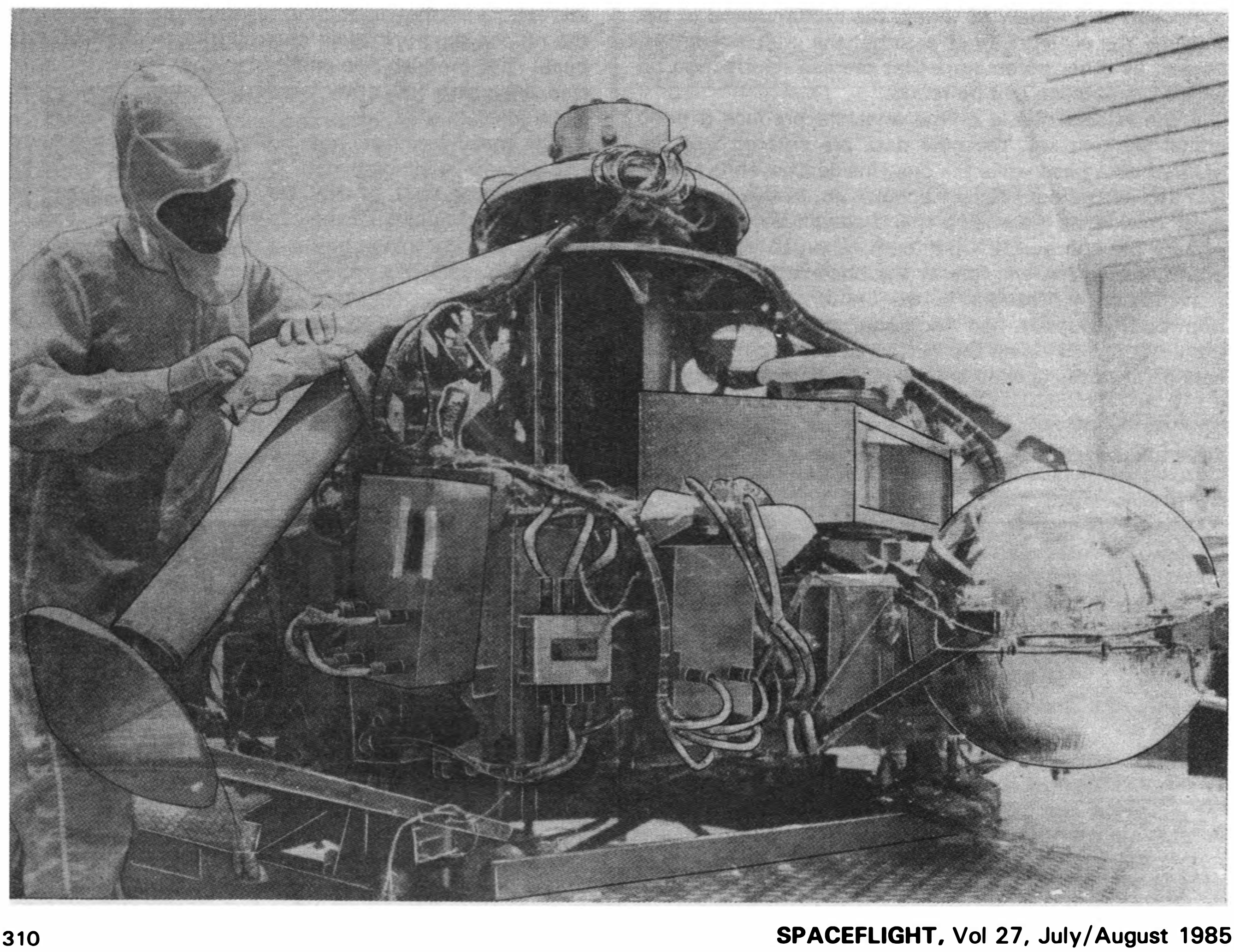
Managing the development of automated planetary spacecraft is an extreme example. In the American programme in recent times, we have been reduced to a single launch for a major mission every few years. Since there is but the one opportunity, scientists try to crowd experiments aboard and the mission objectives become ambitious and complex. High expectations, high public visibility and strong demands for controlled and predictable costs all drive managers and engineers to a conservative reliance on well-understood techniques. Indeed, in many instances, to the use of actual hardware left over from previous projects. Planetary spacecraft thus come to incorporate ancient technologies, even to the point where it becomes difficult to procure spare parts simply because industrial practice has moved on.

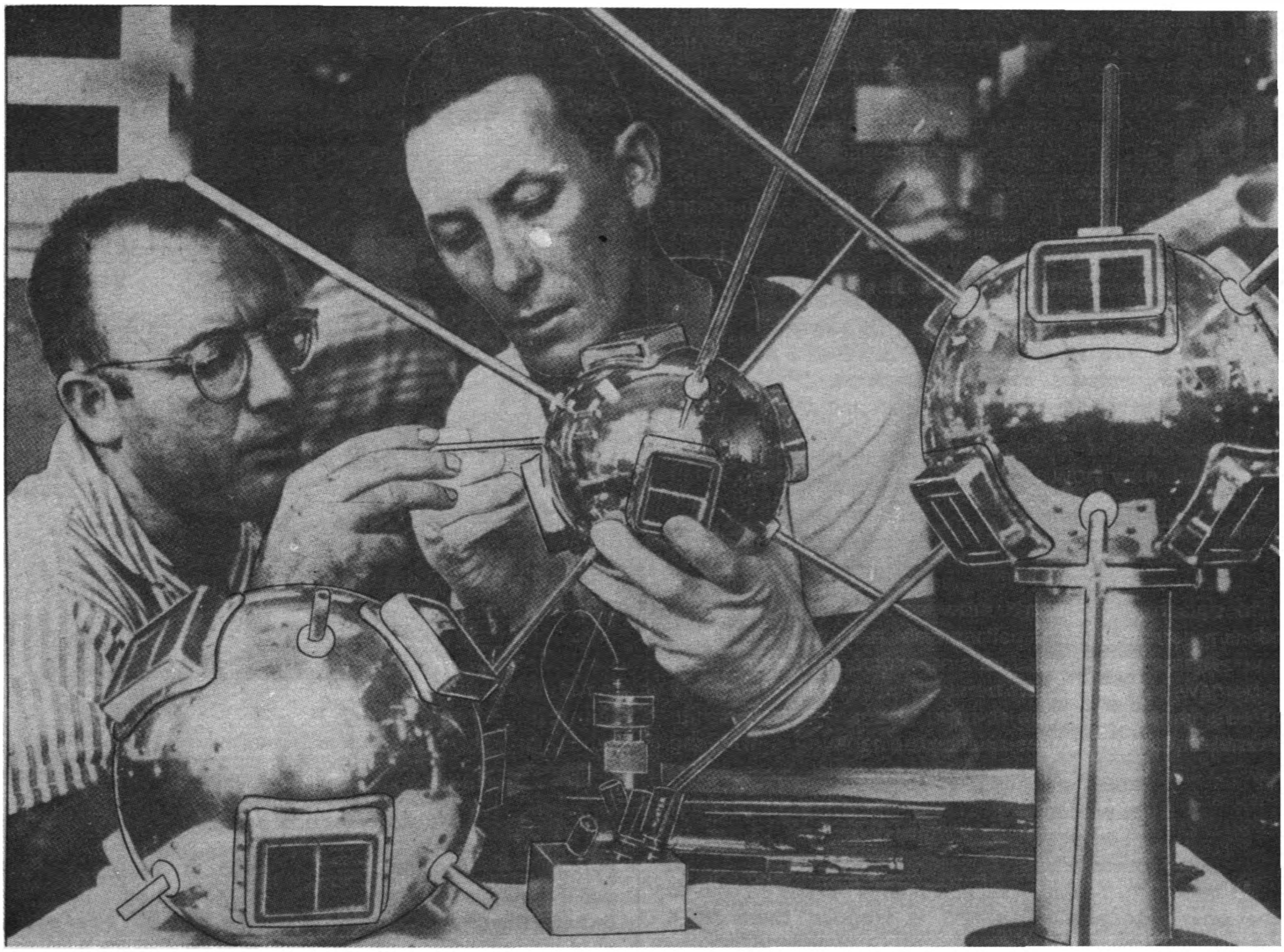
Planetary Program Plans

In a move to counter these trends, NASA, JPL and the scientific community have developed plans [1] for a future planetary programme that includes modest but more frequent missions and treats the need for inheritance differently: for missions where limited performance is acceptable, called the Observer class, commercially-available spacecraft will be modified and used. For more demanding missions, a Mariner Mark II spacecraft concept [2] has been developed emphasising modular design so that new elements can be introduced as needed while preserving inheritance, with its reliability and cost benefits, in as many subsystems as possible. These approaches offer a good prospect of revitalising the American deep-space programme.

Other opportunities exist as well. This article focuses

Planetary spacecraft have tended towards greater degrees of sophistication and size. This is a Viking Mars lander under construction for the 1976 landings on the Red Planet. *Martin-Marietta*





Early satellites were small, simple constructions with few instruments. These are the 15 cm diameter Vanguard satellites, the first one of which discovered radiation belts encircling the Earth. *NASA*

on one that has yet to make an impact but one that holds promise for the future: the micro-spacecraft.

The laws of rocket propulsion and interplanetary flight mechanics dictate an enormous magnification factor between the final payload and the size and mass of a planetary space vehicle at launch. The mass of the Apollo Command Module was less than 1/300 th of the mass of the Apollo-Saturn 5 at liftoff; the mass of a Mars sample-return spacecraft arriving back at Earth may be an even smaller fraction of the total liftoff mass. Clearly there could be benefits from reducing spacecraft mass. Now, a manned spacecraft has to be a certain size because of the people inside it, but there is no obvious limit on the smallness of an automated spacecraft. A small size offers other benefits: small structures tend to be mechanically tougher than large ones, small electronic circuits are faster and for some scientific missions several small spacecraft may give better data coverage than one large one.

With these possible advantages in mind, some of us at JPL, a few years ago, decided to ask how small a deep-space craft really could be made. We started with no particular mission goal; we simply wanted to push the size down as far as possible using then-current technology to see if any interesting opportunities emerged. With encouragement from Dr. Bruce Murray, then the Director of JPL, and using some of his discretionary funds provided for just such exploratory purposes, we carried out a preliminary design for a micro-spacecraft [3].

First we investigated the limits imposed by physical laws. If one views a spacecraft as an information transformer some simple constraints become evident: the machine takes in some radiations and puts out others, so the characteristics of these radiations (and the information that they convey) dictate the sizes of certain spacecraft elements. A remote-sensing orbiter, for example, is typically designed to receive radio waves, heat, visible light, ultraviolet, X-rays and gamma rays coming up from a planet and its atmosphere and to translate the spectral and spatial variations of these electromagnetic phenomena into modulations of one or more radio transmissions to the Deep Space Network on Earth. The translation itself can be performed by microelectronics of almost indefinitely small size, depending more on the state of technology than on fundamental physics. The input and output elements, however, cannot be made arbitrarily small. Optics, detectors and antennae have sizes driven in part by technology (for example, antennae can be smaller if higher radio telemetry frequencies are used) but also in part by natural factors such as the flux and energy of photons available from the planet and the properties of light and radio waves.

These general considerations led us to conclude that a useful deep-space craft, intended to work with the existing Deep Space Network, could hardly be as small as a sugar cube; it might be as small as a telephone or perhaps a typewriter, in contrast to present craft which are more in the piano to car size class.

We then set out to work through the design of a complete spacecraft for a particular, well-defined mission to see what we could learn about the system architecture, with small size as a declared objective. We wanted a mission in deep space, but not one so demanding as to generate a Voyager or Galileo design. After considerable

discussion we settled on an ingeniously simple mission [4] proposed by Dr. H. Porsche of the German DFVLR space research agency—the Cosimi concept.

Cosimi

Dr. Porsche's proposal (the letters stand for COrona Sounding Interplanetary Mission) is an improvement of a radio science experiment that has been performed several times using natural radio sources and the Helios and Viking spacecraft. If a radio beam passes through the coronal plasma surrounding the Sun, properties of the beam are affected in several ways. By measuring these disturbances it is possible to obtain data on a number of questions of interest to solar physicists. The density, character and motions of solar fields and particles near the Sun provide clues to the origin of the solar wind and to the nature of the Sun as a star. If carried out very precisely using two or more radio frequencies near the Sun it can reveal relativistic effects due to the Sun's mass and (with a more complex experimental geometry than that proposed for Cosimi) its angular momentum.

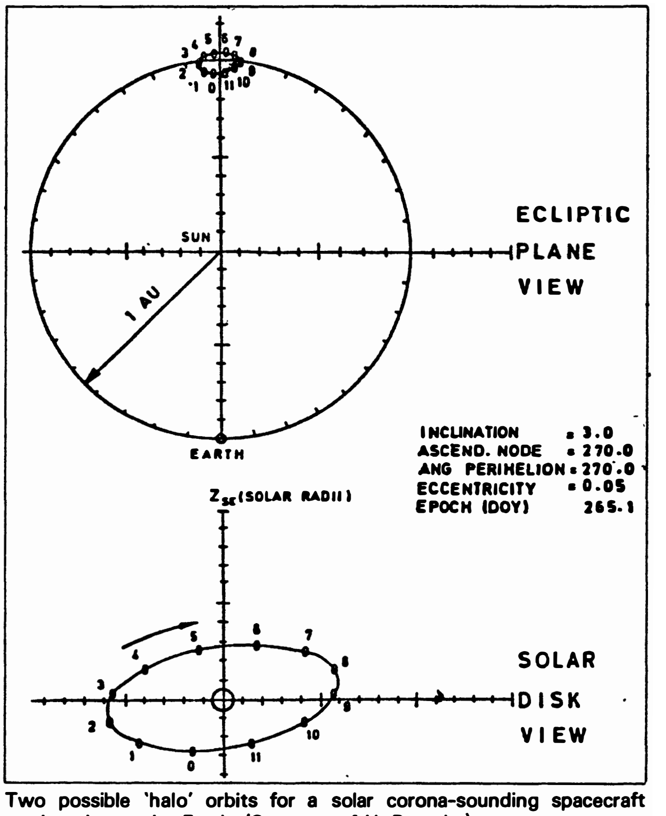
The coronal experiment is possible whenever a radio source passes close to or behind the Sun as seen from Earth, and it has been achieved that way on several occasions. However, the mapping of coronal phenomena both in space and in time could be greatly improved if the radio line of sight were to stay near the Sun instead of simply passing by. This can be achieved by stationing a spacecraft nearly opposite the Earth along Earth's orbit about the Sun, where the craft will describe a 'halo' orbit about the Sun as seen from here. From a guidance and propulsion standpoint the mission is straightforward: the craft is launched at low escape energy, drifts around to the point opposite Earth and is stopped there by a propulsion burn of about a kilometre per second. Instrumentation is also simple: the spacecraft needs only a precision, dual-frequency radio transponder providing two uplinks and two downlinks along the coronal path.

Micro-spacecraft Design Concept

We began the design by asking what minimum combination of systems could do the Cosimi task. We assumed that the Deep Space Network would be able to transmit and receive a coherent (exact multiple) radio frequency pair, 8 and 32 GHz. Radio link performance calculations for the operating range of 2 AU (300 million km) showed that the spacecraft antenna apertures could be less than 1 m^2 at either frequency, assuming modest uplink and downlink data rates in the range of hundreds of bits per second. This result gave us an idea of the size of the spacecraft, since the 8 GHz antenna would probably be its largest element. Using a rough estimate of spacecraft mass, we sized the retrorocket motor (it turned out to be a little spherical solid rocket about 20 cm in diameter) and then began laying out possible configurations.

Up to that point our approach had been fairly conventional as dictated by the objectives and constraints, but now the wild ideas began to flourish.

Having decided to use high-gain antennae on the spacecraft because of their great advantages with regard to the power required, we needed attitude control to keep the antenna beams pointed toward Earth. However, this beam pointing was really needed only at the operating station where, as seen from the spacecraft, Earth and Sun would be close together in the sky. Thus the spacecraft could be designed simply to face the Sun - provided one was willing to accept very limited (at times, zero) data rates while the spacecraft was drifting toward its station. We contemplated electrical beam-steering with a phased-array antenna, and we considered conical and



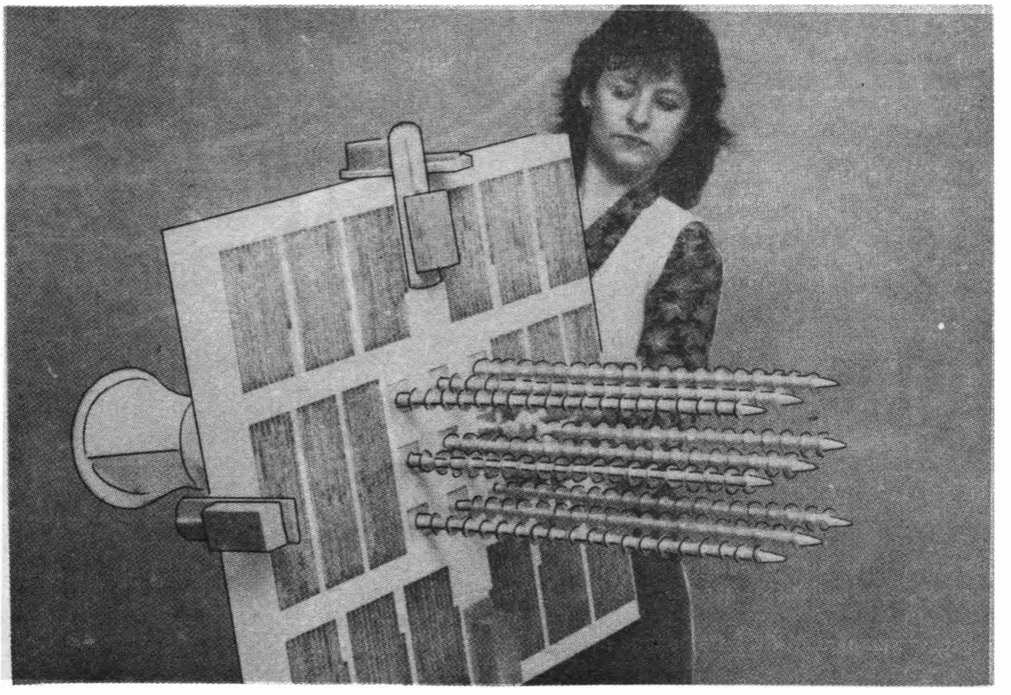
Two possible 'halo' orbits for a solar corona-sounding spacecraft stationed opposite Earth. (Courtesy of H. Porsche).

pyramidal spacecraft configurations in an attempt to achieve photodynamic stability (i.e. to use light pressure to keep the craft oriented toward the Sun) but after some study we rejected both concepts and settled for a pulsed plasma jet attitude control system. Micro-thrusters for such a system are quite practical and have been successfully tested at JPL and elsewhere.

For the 32 GHz antenna we selected a flat phased array consisting of more than 8000 tiny dipoles with no electrical beam steering. Beam pointing, if required, would be done by tilting the whole spacecraft off-Sun, using the tiny plasma jets. The 32 GHz transponder was our first truly unconventional subsystem: the signal electronics and power amplifiers were microcircuits embedded in the planar antenna, with one amplifier behind each of the thousands of little dipoles! With such a design nobody could accuse us of leaning too much on inheritance. The next outlandish proposal was to integrate a solar photovoltaic power array into the flat antenna, with the DC power-collection network combined with the array of RF dipoles, all buried in a silicon structure. Needless to say, we arranged the attitude-control electronics also in a flat array on the back side of the antenna with a covering (perhaps just paint) to give the right heat rejection for thermal control of the whole structure. For structural rigidity, vibration resistance and acceptance of the retromotor thrust, we deepened the flat structure beyond its immediate packaging needs, thus providing volume for components (such as small scientific instruments) that might be added for other missions. In another bid for flexibility, we designed the 8 GHz transponder and its multi-rod antenna as a separate subsystem using more conventional design concepts and mounted this whole unit in a square hole in the centre of the 32 GHz assembly.

Implications of the Design Study

The micro-spacecraft as described above will never fly. If it were decided today to carry out the Cosimi mission the simpler, cheaper and more reliable way to go would



Carol Lachata of JPL holds a full-scale micro-spacecraft mockup. *NASA/JPL*

be to install conventional transponders and antennas on an off-the-shelf spacecraft in the Pioneer or Observer class, and put the spacecraft on station using any of several available launch and retropropulsion systems. For the mission as defined, any advantages of smallness are outweighed by those of inheritance. But we knew that at the outset; our objective was not to upset a present, well-developed inheritance trend but rather to point toward a parallel inheritance trend that could be started and nurtured 'off-line,' with its product being switched into the main stream at some future time. Advanced missions in the future, such as the return of samples from Mars or the emplacement of sensor networks on Mars or the outer planets' satellites, will return large premiums for spacecraft size reduction – but will there be a family of small spacecraft available by then with adequate inheritance of their own? Not unless something is done in the meantime. We continue to search for ways to introduce micro-spacecraft techniques in missions where this is not precluded by a combination of risk and cost constraints, so as to start constructing the parallel inheritance trend.

Other Small Spacecraft

Tiny space machines are, of course, nothing new. Ever since the Vanguard 'grapefruit' satellite of 1958, there have been occasional launchings of midget devices for various purposes. The Tetrahedral Research Satellites, built by TRW and launched in 1963, were 16.5 cm on a side and weighed only 0.7 kg each. Both they and the little Vanguard functioned well for long periods and are still silently orbiting Earth.

Several small (about 5 kg) spacecraft have been built and successfully flown, usually in a piggyback mode on other missions, by amateur organisations aided by donations from industry. The Oscar radio satellite is an example of this class. For missions of that sort, the risk environment is right for the use of new technology, but development funding limits may preclude it.

An elegant, small deep-space craft is the Japanese Planet-A, intended to observe Halley's comet in 1986. Planet-A and its test precursor, Sakigake, had to be small and light to come within the capability of the available launch vehicle, but otherwise were subject to the risk and cost considerations that are normal for highly-public missions in deep space. Therefore, though they do incorporate some microelectronics, these spacecraft are fairly conventional in design.

The Challenge

We thus continue to be faced with an interesting problem. We would like to start a new inheritance chain based upon already-known micro-technologies; we know that this could yield benefits in the future, but we have yet to find a way to muster the needed intial investment and gain acceptance of the initial risks, both as to reliability and cost. Some of NASA's near-term programmes are actually headed in the other direction, namely toward larger, heavier designs as a means of saving money and increasing assurance of success. An example is the 1500 kg Spartan spacecraft, a simple design with modest performance, ingeniously fitted into Shuttle constraints, which place a high premium on cargo-bay space and operational simplicity but do allow plenty of mass. Perhaps the deep-space micro-spacecraft inheritance chain will have to appear somewhere outside the main American civil space programme and make its way in by lateral transfer, thus avoiding the risk and cost barriers that have blocked it up to now. However this happens, the result offers great promise: the faster we need our spacecraft to go, the greater will be the advantages of microtechnique. Ultimately it may be among the technologies that enable us to reach relativistic speeds and send exploring messengers to the stars.

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CANADA'S SATELLITE SYSTEM

By Peter Jedicke and Clifford Cunningham

The advent of the communications satellite has proved to be a great benefit for the sprawling territories of Canada. The authors describe the history and present use of such satellites in the most extensively-developed domestic system in the world today.

Introduction

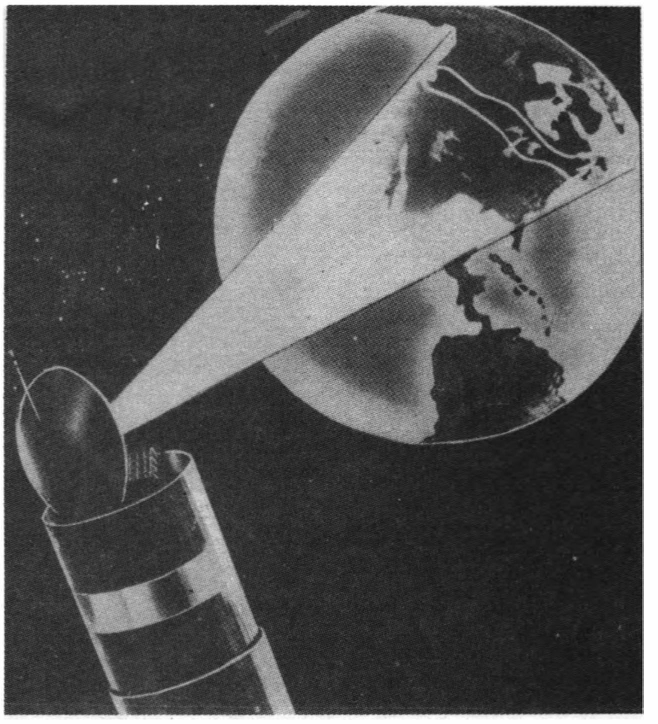
Canada's 24.3 million [1] people are unevenly distributed over the second largest geographical area in the world under the control of a single political entity, totalling some 9.2 million km^2 of land and 0.76 million km^2 of inland fresh water. The northern reaches are sparsely populated or even uninhabited: 89% of the land area contains no permanent settlements and 90% of Canada's population lives within 100 km of the southern border [2]. As a result, internal communication has always been a significant challenge.

On 20 August 1964 Canada became a signatory to the treaty that set up the international telecommunications satellite consortium, Intelsat [3], and acquired a 2.25% investment share [4]. Canada's representative in Intelsat was the Canadian Overseas Telecommunications Corporation, which has since changed its name to Teleglobe Canada. Progress was swift. For the Games of the XXI Olympiad in Montreal in 1976, the system was used for the first time to link Canada's domestic communications satellites with the rest of the world. Today, 'about 35% of Teleglobe Canada's traffic travels by satellite and the rest by submarine cable' [5].

Canada's federal government recognised early on that this technology would have important applications to domestic communications. A report submitted to the Science Council stated that 'space technology is so directly related to the needs of a large, sparsely populated country that it cannot be ignored' [6]. A White Paper was prepared in the spring of 1968 in which the government outlined its plans [7]. A bill was presented in the House of Commons to form a new organisation to pursue this exciting opportunity [8]. The name of the new organisation was Telesat Canada and its mandate was to 'establish satellite telecommunications systems providing, on a commercial basis, telecommunications services between locations in Canada' [9]. As has been the pattern in many high-technology segments of industry, the legislation specifically directed the new organisation to promote Canadian development: 'The company shall utilize, to the extent practicable and consistent with its commercial nature, Canadian research, design and industrial personnel, technology and facilities in research and development connected with its satellite telecommunications systems and in the design and construction of the system' [10]. The ownership of Telesat was also innovative: it was to be shared by the federal government, various telecommunications companies and the public at large. Telesat is not a Crown Corporation.

Summary of Telesat Canada Satellites and Launches

	Launch	Launcher	Station
Anik A1	Nov. 72	Delta	104W
Anik A2	Apr. 73	Delta	109W
Anik A3	May 75	Delta	114W
Hermes	Jan. 76	Delta	116W
Anik B	Dec. 78	Delta	109W
Anik C1	Apr. 85	Shuttle	
Anik C2	Jun. 83	Shuttle	105W
Anik C3	Nov. 82	Shuttle	117W
Anik D1	Aug. 82	Delta	104W
Anik D2	Nov. 84	Shuttle	111W



Approximate coverage pattern of an Anik satellite. *Hughes*

Practical Experience

Concurrent with the development of a political infrastructure for the implementation of a domestic communications satellite programme was the development of Canadian expertise in the design and construction of space satellite hardware. On 29 September 1962 the Alouette 1 satellite made Canada the third nation in the world to have built its own Earth-orbiting instrument package. Alouette 1 was a project of the Canadian Defence Research Telecommunications Establishment. Its scientific mission was primarily concerned with taking measurements of the Earth's ionosphere from above. In return for full access to the resulting data, the United States provided the launch of Alouette 1, as Canada had decided that 'the provision of Canadian launch vehicles... clearly would be excessive' [11]. The use of US launch facilities and equipment for reaching Earth orbit has continued to the present.

Alouette 1 was such a rousing scientific and technical success that it resulted in over 400 research papers, more than any other satellite [12]. Its backup, Alouette 2, was launched on an upgraded mission on 29 November 1965. With the further co-operation of the United States, the United Kingdom, France, Norway, Japan and Australia, Alouette 2 was itself followed by the Canadian-built Isis 1 and 2 satellites (International Satellites for Ionospheric

Studies), launched on 30 January 1969 and 1 April 1971, respectively. Between them, these four missions accumulated 45 years of operation in orbit and established Canada's reputation in the field of space technology.

Among the results of the Alouette/Isis programme was a better understanding of the propagation of electromagnetic signals in and through the atmosphere above Canada, including the effects of aurora at high latitudes [13]. Canadian companies had proved they could develop the technical skills necessary to be productive in the satellite industry and the federal government had demonstrated its willingness and ability to encourage and participate with commercial enterprises in this field.

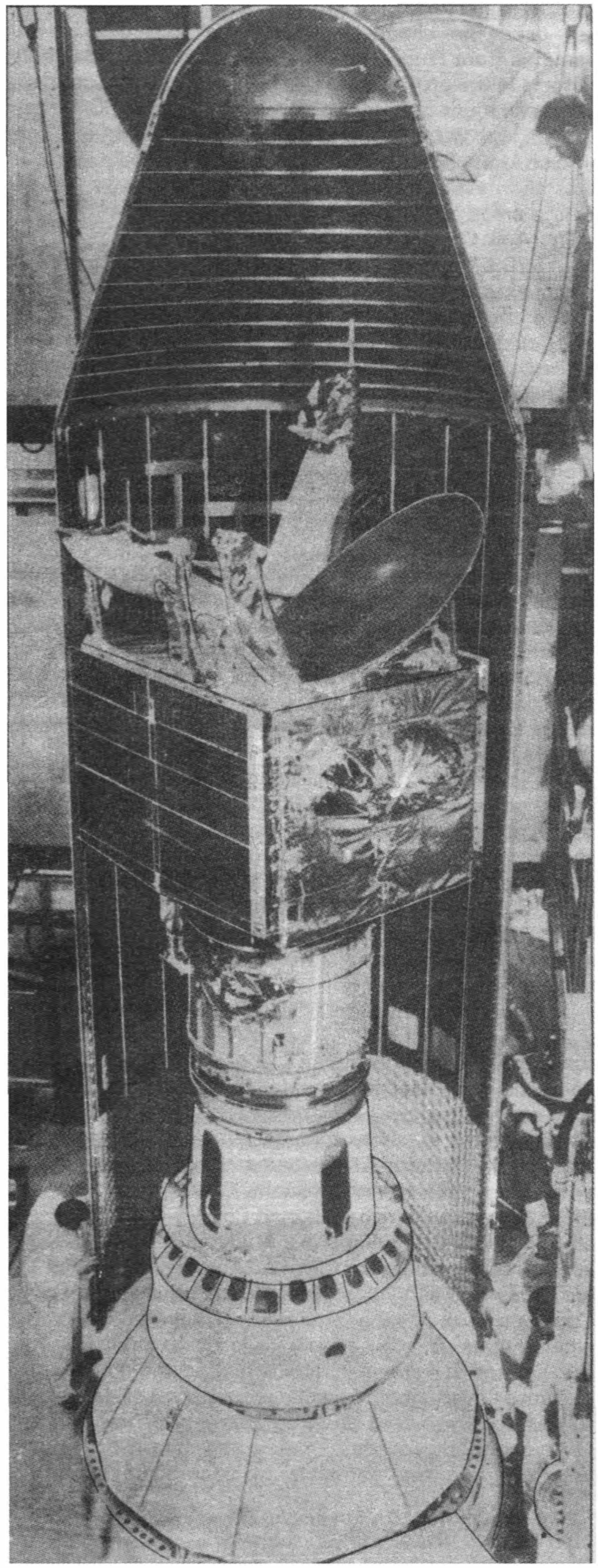
Into this climate came the new organisation charged with developing a domestic communications satellite system. Telesat Canada officially opened for business on 1 September 1969. Telesat quickly concluded that a communications satellite for domestic purposes could be located in a geostationary orbit [14]. The only previous satellites intended for domestic communications had been located in lower orbits, such as the Soviet Molniya series; the only previous communications satellites in the geostationary arc were intended for international traffic.

For Canada's space hardware, the name 'Anik' was chosen in a nationwide contest; it is the Inuit (Eskimo) word for 'brother.' Anik 1, now known as Anik A1, was on station in orbit on 17 November 1972 and commercial operations began on 11 January 1973 [15]. Anik 2 and Anik 3 (now Anik A2 and A3) were launched in 1973 and 1975. These three identical satellites, 87% built by Hughes Aircraft Company in California [16], were cylindrical, about 1.80 m in diameter and 3.40 m high, massing 560 kg. They were spin-stabilised [17], topped by a despun oval dish antenna and powered by solar cells that completely covered their bodies and were rated at 235 W. The communications uplink was at 6 GHz and the downlink at 4 GHz, with 12 channels on each Anik. Characteristics of these early Aniks can be found in *JBIS* [18].

The next milestone in Canada's domestic communications satellite history was Hermes, an experimental communications satellite developed co-operatively by the Canadian federal government's Department of Communications (DOC) and the United States and built primarily in Canada. Hermes, originally known simply as the Communications Technology Satellite, was never integrated into Canada's domestic communications system. However, it did demonstrate both technology and applications in the 14/12 GHz region.

Hermes was designed with a 12 GHz travelling wavetube amplifier, a lightweight, high-power extendable solar array and a three-axis stabilisation system. All of these characteristics represented significant innovations [19]. Canadian reliability was demonstrated by the longevity of the satellite: it exceeded its design lifetime by more than a factor of two.

Hermes was followed by Anik B. It was a single satellite almost identical to Hermes but belonging solely to Telesat Canada. It was used mainly for further tests and demonstrations, similar to those conducted with Hermes, by the DOC. Well over a dozen projects to test, develop and demonstrate the socio-cultural as well as technical aspects, were carried out. Among these were news gathering by the Canadian Broadcasting Corporation, direct-to-home television in several areas of Canada, teleconferencing among Inuit communities in the far North, transmission of medical data between remote locations and hospitals in Newfoundland and linking of three radiotelescopes for Very Long Baseline Interferometry. The scope, range and success of such programmes vindicated the role of satellites in domestic communications.



High in the service module atop its launch pad at Cape Canaveral, Anik B is shown as it was undergoing its final check-out before lauhch in 1978. *NASA*

Only limited use was made of Anik B in the domestic communications system. It was the world's first 'hybrid' satellite, the 12 channels in the 6/4 GHz band used commercially and replacing the capacity of the older Anik A1. Also, in 1980, the world's first commercial service in the 14/12 GHz band was inaugurated when

Telesat leased one channel to 'La SETTE,' an organisation that used the channel to distribute videotaped programmes from France to Community Antenna Television systems in the province of Quebec. Testing with commercial applications also included evaluation of a 90 Megabaud digital link and digital modulation systems, Time Division Multiple Access service trials for business applications and development of thin-route telephone service to remote areas of the province of British Columbia [20].

The Anik C satellites were the first application of the mid-1970's technology dedicated solely to the domestic communications satellite system. There are three examples of the Anik C series, again constructed by Hughes with substantial subcontracting by Spar Aerospace Limited, a Canadian company with extensive experience in satellite components. Partly because of Shuttle delays, the first two were placed in storage.

When Anik C3 was ready, so was the Space Shuttle. In order to minimise the expense of moving satellites into and out of storage, Anik C3 was launched first. The Anik C series is presently the mainstay of TV satellite use in Canada.

The two members of the Anik D series will replace the original Aniks in the 6/4 GHz band, still used for voice and data transmission. The prime contractor for these satellites was Spar Aerospace, a major responsibility for a Canadian company. Also for the D series, the DOC expanded its David Florida Laboratory, Canada's first facility for integrating and testing large satellites, outside Ottawa.

The immediate future will bring Canada into close cooperation with the European Space Agency. Contracts for design and manufacture of components for Olympus have been granted to Spar Aerospace. This will be a new, high-power communications satellite to be launched in 1987 and capable of direct-to-home broadcasts, high density international communications, voice, data and video links to small Earth terminals and very high capacity intercity telecommunications [21].

A considerable investment has also been made in Earth station equipment for linking the satellites with their commercial users. Command and control of Canada's domestic communications satellite system is accomplished from a control centre in Ottawa, which communicates with the satellites through a major Earth station at Allan Park, Ontario. At the same location is one of the two prime Earth stations for the Canadian system; the other is at Lake Cowichan, British Columbia. Each of these stations has a 30 m antenna and provides trunk message service across southern Canada. Another station on the east coast at Mill Village, Nova Scotia provides Teleglobe Canada's links to the international system. Over 100 smaller stations, with antennae up to 10 m in diameter, are situated at various locations around the country.

Almost every communications carrier has easy access to this system, which provides a variety of transmit and receive options for data, voice and television signals, depending on the demands at each installation. For example, the Canadian Broadcasting Corporation uses the satellite system not only for its network traffic but also to distribute programming to remote communities in the North.

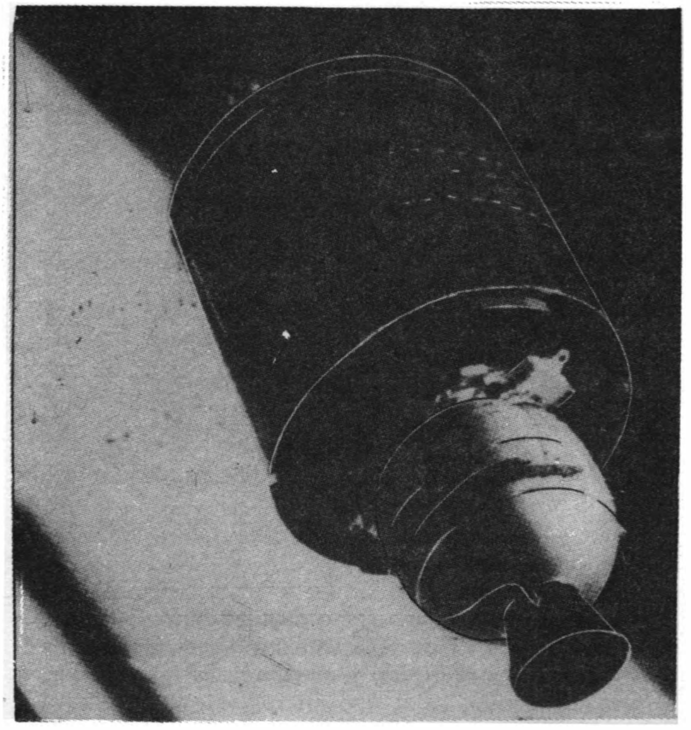
Satellite Characteristics

	Hermes	Anik B	Anik C	Anik D
Design Life (yrs)	2	7	10	10
Height (m)	1.88	3.23	6.40	6.57
Diameter (m)	1.83	2.05	2.13	2.16
Weight (kg) (at launch)	674	923	1080	1128
Stabilisation	3 axis	3 axis	spin	spin

The first Anik satellite was launched in November 1972. *Hughes*

Another example of the satellites' effect on life in Canada: a consortium of Canada's local Community Antenna Television systems, known in Canada as 'Cable TV' and available in almost every city in the country, joined the domestic communications satellite system when they expressed interest in owning Earth stations for distribution of children's programmes, public affairs and live broadcasts of question period from the House of Commons on one channel, for several hours each day in English and French [22].

Considerable progress has been made toward the goal, defined in the 1960's, of using satellites to contribute to Canadian unity. In their entirety, 'Canadian telecommunications networks form a vast grid stretching across land and water from the East to West coasts, with branches north and south and extending into virtually every com-



Anik C2 is released from Shuttle *Challenger* in June 1983. *NASA*

munity. The network consists of open wires, cables, microwave systems, the domestic communications satellites and a vast array of different types of switching facilities. Their function is to link terminal devices, everything from telephone to computers, with a compatible terminal at the other end' [23].

Now that the technical capability and reliability of the domestic communications satellite system has been established and recognised, new developments have shifted primarily to the legislative and regulatory areas. There has been considerable public controversy over the specific details of how the system will continue to play a major role in Canadian life.

A system so easily accessible to so many carriers with diverse business interests is also of serious concern to legislators, consumer advocates and industry managers. The DOC has announced that any terrestrial common carrier, broadcaster or business will be permitted to apply for a licence to operate uplink stations to access all of Telesat Canada's satellites. This policy, which parallels the interconnect decision governing federally regulated telephone companies, will take effect 1 April 1986. The DOC hopes to stimulate the satellite-related manufacturing industry, just as the earlier move created a telephone-interconnect industry.

The debate is wide-ranging, with industry leaders hoping to increase their activity. The DOC has planned a two-year phasing-in period to set technical standards and expand capacity.

Telesat Canada insists that the DOC's technical and operational standards for customer-owned uplink stations must be firm and foolproof to protect the national satellite system from 'unlimited numbers of technically inexperienced private users.' Furthermore, Telesat intends to remain the main Canadian supplier of Earth stations, both for its own needs and those purchased by users. It has, therefore, asked the federal government to repeal the requirements in the Telesat Canada Act that it place a high priority on buying Canadian-made products.

Canada can be proud of having the most fully developed and integrated domestic communications satellite on the planet. The specific arrangements might change but ...long after roads have disappeared as a means of communication, communications satellites will remain' [24].

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THE PROTON LAUNCHER

By Alan Bond and John Parfitt

The Soviet Proton launch vehicle has been an enigma for some 20 years. There have been no block disclosures of its size and capabilities, only tantalising glimpses and snippet releases of data. To add to this has been a host of articles portending to give detail of the unknowable at a resolution that, in the main, has been fanciful.

Introduction

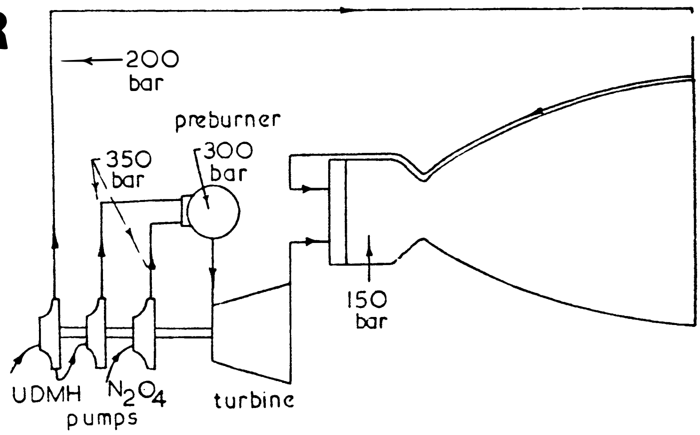
At last, with the launches of the Vega 1 and 2 Venus/Halley comet probes on 15 and 21 December 1984, respectively, the Soviets have released comprehensive TV views of the Proton, its control room and the first 50 seconds of flight. Several features are clear. Proton is tandem staged with with six wrap-around boosters and a similar diameter central core, confirming the general layout, but somewhat different in size and proportions to the illustrations published in the West from 1973. Glushko's statement that the engines employ a preburner cycle [1] is substantiated since no turbine exhausts are visible. The evident oxidiser rich start is also consistent with the statement that the preburner is oxidiser rich. The film shows that the vehicle lifts off from the pad almost immediately after engine ignition, unlike the Soyuz launcher which takes some time for thrust build-up before lift-off. Also, the pad does not have the counter-weighted hold down arms used on the Soyuz pad, suggesting more conventional clamps. The film also confirms that the core stage is not ignited on the ground. This is shown clearly, as the vehicle heads downrange, by the glow of the engines from the six boosters surrounding the dark central core.

Interpretation

Several pieces of information can now be combined to derive a good assessment of the vehicle. V.P. Glushko and V.N. Bychkov have published [1,2] considerable data on the engine (the RD-253) and a picture has also been released [3]. The Soviet documentary film *Steep Road to Space* released in 1973 gave the only views of the Proton launcher previously revealed. The implied connection with the Salyut 1 launch suggested that the payload shown was a Salyut. However, it is now clear that the vehicle shown was a four stage Proton and the payload must have been either a Zond or interplanetary craft. The implication of this on scale are discussed later.

Table 1. Suggested Proton mass distribution

	Mass	Notes
Boosters	100 t	91 t propellant
Core	100 t	91 t propellant
Upper Stage	60 t	53.7 t propellant
Attach fitting and Guidance and Control bay	2 t	
Shroud	1 t	
Payload to parking orbit	20.2 t	Including interplanetary stage



NB: This cycle is derived from pumping power and cooling capacity studies.

Fig. 1. Postulated RD-253 cycle.

The Soviets have given some payload masses for the first three Proton (two stage version) flights, as well as for the three stage Proton 4 and later Salyut vehicles. Masses for several lunar and interplanetary craft have been released.

Turning first to the RD-253 engines. From V.N. Bychkov's values we observe:

Preburner pressure = 300 atm

Combustion chamber pressure = 150 atm

Pump power (for 7 pumps?) = 1.125×10^8 watts

The propellants are probably nitrogen tetroxide (N_2O_4) and unsymmetrical dimethyl hydrazine (UDMH), based on statements in Refs. 1 and 2, and since the preburner is oxidiser rich the cycle is possibly as shown in Fig. 1, since this gives the maximum combustion chamber pressure attainable.

It was stated in Ref. 2 that 75% of the fuel entered the preburner. This seems unlikely since the turbine would then have severe cooling problems. However, 7.5% would allow the turbine to run at ~470°C, permitting titanium construction. Great importance has been given to titanium in Soviet engine construction and the low mass of the Proton turbo pump has also been stressed, quoting 1500 kg for all of the RD-253 pumps (7?), giving 214 kg per engine. Assuming hydraulic and turbine efficiencies of about 65%, the optimum pressures for the cycle shown would be about 290 bar in the preburner and 160 bar in the combustion chamber, substantiating the Soviet claim. Allowing for nozzle efficiencies and assuming an exit pressure of 0.4 bar, the engine should deliver a specific impulse in vacuum of 325-328 sec with an area ratio of 35-40. This geometry is consistent with the published photograph of the engine, again substantiating the Soviet claim. The mixture ratio would be about 2.88 oxidizer/fuel for optimum performance. With oxidiser and fuel densities of 1450 and 790 kg/m^3, respectively, and the delivery pressures shown, we expect the flows to be 1169 kg/s of UDMH and 3366 kg/s N_2O_4. Since there are seven engines this suggests a thrust per engine of 211 tonnes in vacuum. The Soviet statement was that the Proton had a thrust three times as great as Vostok. Assuming this means booster thrust + two times the core as used for the quoted Vostok thrust, this would give a vacuum thrust per engine of 225 tonnes, lending some credibility to the engine thrust calculated above.

At the time of launching Proton 1 it was stated that the vehicle had an installed engine power of over 60 million horsepower. Assuming that this is vacuum thrust

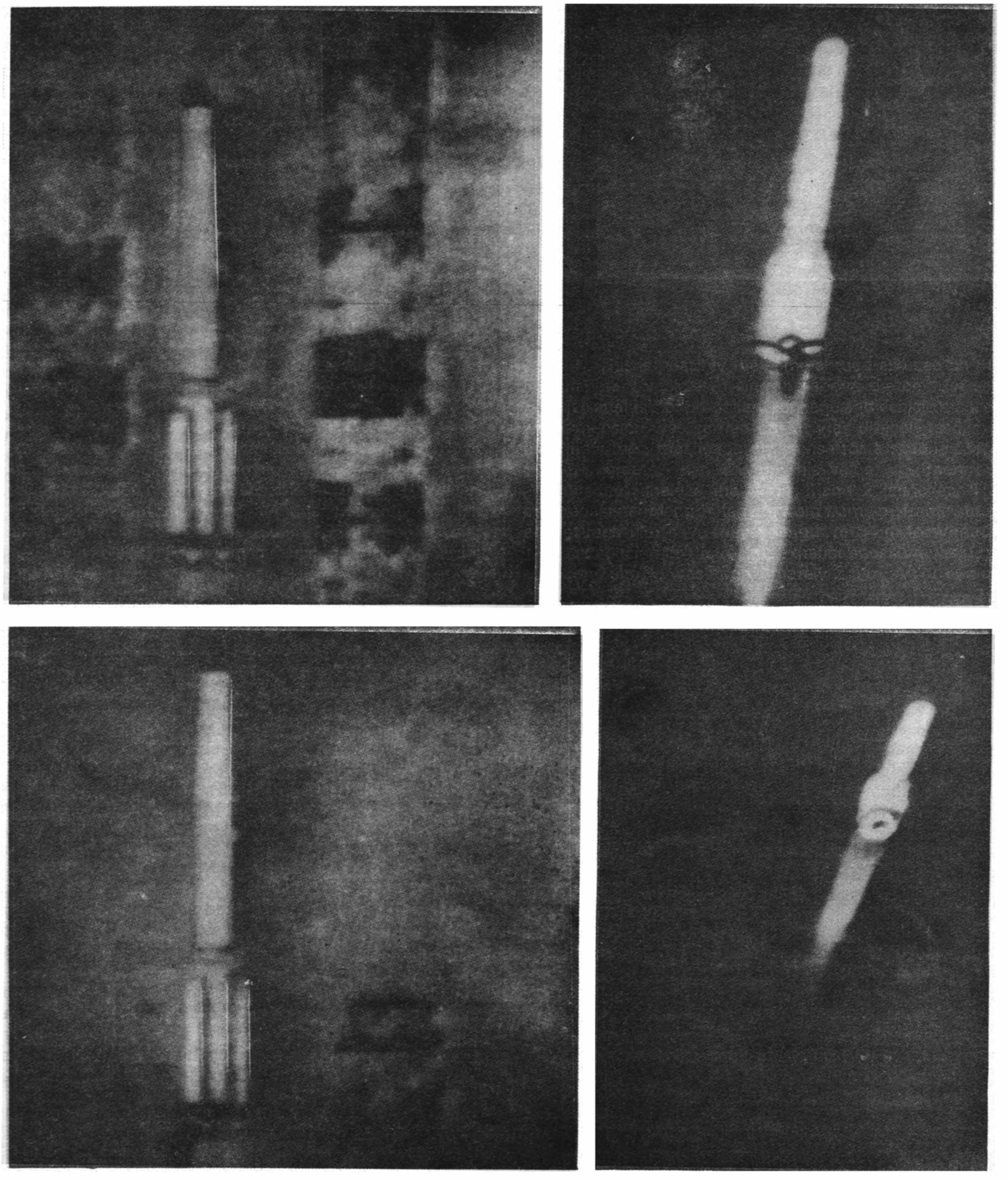


Fig. 2. Sequence from one of the Vega launches in December 1984.

times effective exhaust velocity as for Vostok, it would correspond to seven engines at over 205 tonne thrust each.

The analysis of the Proton vehicle from the Vega launches requires a known dimension. The film *Steep Road to Space* was originally employed since the dimensions of Salyut are known with reasonable accuracy. However, the revelation that the film does *not* depict a Salyut launch casts doubt on that derived dimension. The only other scale available is the shroud dimensions offered for the commercial Inmarsat launch, giving a 3.3 m internal envelope [4]. This is possibly the same shroud as used on the interplanetary vehicles. Using the above sketchy data an iterative analysis of propellant tankage and vehicle masses and dimension was carried out. It was difficult to derive a configuration that made any sense for a second stage diameter greater than 3.8 m. This value was therefore employed to analyse the Vega 1 and 2 launches. The most consistent length derived from frame by frame study of the Vega film gave then a length of 54 m for Vega 2. The half spacing of the rocket exhaust shock waves (first to second shock) was approximately 2.5 m. A correlation

derived by one of the authors gives vacuum thrust to about ± 5% for engines between 3 and 213 tonne thrust and propellants covering High Test Peroxide/Kerosine, N_2O_4/Aerozine 50 and lox/hydrogen, with conical and contoured nozzles, is:

$$F_{vac} = 34.07 \text{ (shock wave half spacing)}^2$$

Applied to the Proton this gives F_{vac} - 212.9 tonnes per engine. The time taken for Proton to accelerate through its own height (54 m) was 5.3 sec, giving a launch thrust/weight ratio of 1.39, which is coincidentally about the thrust/weight ratio of the Soyuz launcher.

Assuming from the previously calculated area ratio a sea level thrust of 0.86 of vacuum thrust, the lift off mass of Vega 2 is calculated to be 790 tonnes. Trajectory simulation of the early Protons, Proton 4, Salyut and the interplanetary missions suggested a good fit with the mass distributions given in Table 1. This gives a total of about 783 tonnes. Thus, in spite of the inevitable inaccuracies of these different analytical routes, it is possible to compromise to a reasonably consistent set of values.

Just before beginning the pitch programme on the Vega launches (approximately 18 sec) a smoke plume is seen to emerge from the base of the vehicle between the core and one booster which then continues to run as a jet of moderate dynamic pressure. Its origin is not clear but it has the apperance of a solid cartridge started mono-UDMH gas generator, of a type similar to that which drives the RD-119 turbo pump. Its function is unknown. It is relatively small and several possibilities are electrical auxiliary power unit, hydraulic system, tank boost pump system and tank pressurisation. However, all of these would be expected to function from launch and so are not very convincing. Some form of dump coolant flow of the core engine or a purge system has also been suggested, although it is no more convincing. A further possibility is cool gas injection into the recirculation zone which must exist between the exhausts of the boosters. Such an injection could be required to prevent the core engine from being overheated during booster operation by hot engine exhaust gasses.

Observations

The Proton vehicle appears to be compact and well designed, converse to the standard Western viewpoint on this vehicle. Its launch mass is probably closer to 800 tonnes than 1000 tonnes, the value usually quoted. The core/booster combination suggests that it could have been originally optimised as a weapons system of about 20 tonnes payload over 11,600 km. This suggests that it may have been meant to carry a very large thermonuclear warhead. Another factor suggesting its weapons-related origin is the use of storable propellants. However, the flight record suggests that if that were the case, then it had been redirected as a space launcher even by its first successful test flight in July 1965.

The engines for the Proton, the RD-253, are remarkable. They began development in 1961 according to Glushko and at the time of their first successful flight were the most sophisticated operational engines in the world. They are still the most sophisticated storable propellant engines and have no Western counterpart. The thrust to weight ratio is very high (130 quoted) and its specific impulse must also be high from the known characteristics (chamber pressure and area ratio). At the time of their introduction, the RD-253 engines would have been second only to the Saturn 5 F1 engines in thrust, but considerably superior to it in performance. The high launch accelerations used on Soviet space launches suggest that their engines have a relatively high thrust to weight ratio, assuming that they are optimised for minimum trajectory losses. Glushko has said that the development of these engines and similar ones (possibly lox/UDMH engines for the TT-5 lunar vehicle?) gave considerable problems with combustion instability. The Proton has never been man-rated and presumably the noise/vibration environment of the vehicle still precludes this.

The Proton launch vehicle has been used in three versions:

SL-9(D)
Six strap-on boosters and core, used for launching the first three 12.2 tonne Proton satellites in 1965 and 1966. It has been reported that in this initial version of the vehicle the core was ignited on the ground together with the boosters. If this were the case, then, as the boosters and core are similar in size and hence propellant capacity, orbit could be achieved only if propellant was cross fed to the core engine from the boosters until their separation. The core would then transfer to its own full propellant tanks to achieve orbit. There is presently no resolution to this conflicting data.

SL-12 (D-1-e)
Six strap-on boosters, the core, and a third and fourth stage. The first three stages are used to place the fourth stage and payload into low Earth parking orbit. The fourth stage is then used to place the payload on an escape trajectory, in the case of lunar and planetary probes, or into geosynchronous orbit for communications satellites. First launch was Cosmos 146 in March 1967, probably with a Zond circumlunar spacecraft that failed to leave parking orbit.

SL-13 (D-1)
Six strap-on boosters, the core and a third stage. This is essentially the SL-12 minus the escape stage. This version is currently used for launching the 18.5 tonne Salyut space station and associated 'Star' modules. First launch was the 17 tonne Proton 4 in November 1968.

The Proton has been offered as a commercial launch vehicle in the West. It is now into its 'second century' of launchings and appears to be reliable and efficient with the launch down to a routine event.

Other information present in the Soviet TV footage was the trajectory display on the control room wall, showing staging events, booster impact range and the trajectory dispersion corridor. The resolution, however, was poor and provided only a general background of launch data to the vehicle.

Acknowledgements

We gratefully acknowledge the contribution by Frank Miles of Independent Television News, who provided the opportunity to study the videos of Soviet TV coverage of the Vega 1 and 2 launches.

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A WALK AROUND THE WORLD

By David Shayler

On 3 June 1965 astronaut Ed. White became the first American to make a space walk. This article briefly reviews the achievement two decades on.

Origin of Extra-Vehicular Activity

The idea of astronauts venturing outside their spacecraft in orbit became part of the Gemini programme in 1962 when preliminary reports were made on the effect of opening the spacecraft hatch for a 15 minute period. NASA had long realised that an EVA capability was a necessary part of future missions, as recent Shuttle missions have demonstrated.

The development of the Gemini pressure suit began in 1961, with an EVA capability considered from the beginning. This was followed by work on an umbilical cord to restrain and supply the astronaut with oxygen and communication links. Tests on leaving and reentering Gemini were performed in 1964 and the development of the life support equipment began.

On 27 July 1964 NASA announced the crew for Gemini 4, the second manned flight of the series, as James McDivitt, Command Pilot, and Edward White, Pilot. White, then 34, would perform an experiment that would expose him to the 'hazards of outer space without the protection of a spacecraft.' He would perform a simple EVA by standing on his seat and putting his upper body through the open hatch; an actual EVA would be attempted on a later flight.

In January 1965 White began a series of zero-g Gemini ingress and egress exercises during parabolic flights in NASA KC-130 transport aircraft. The following month he ran through a stand-up EVA at a simulated altitude of 48 km during the Gemini 4 altitude chamber test programme.

Competition

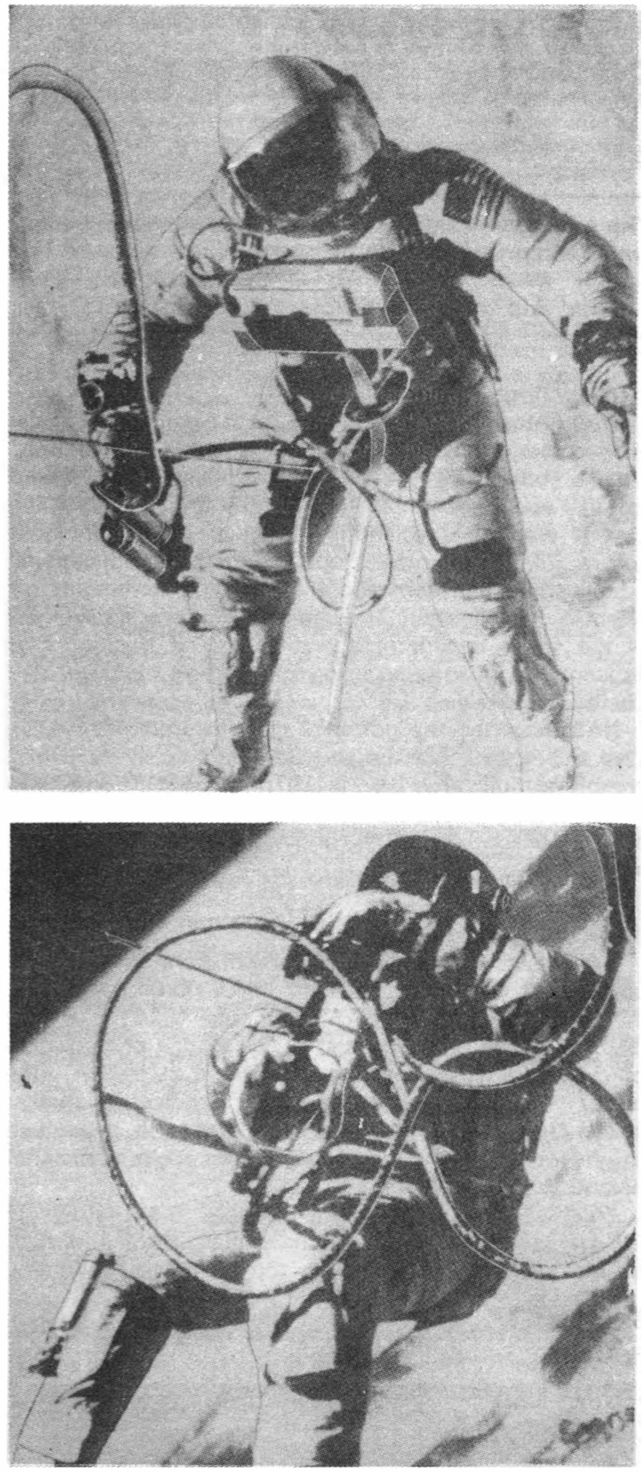
On 18 March 1965 Soviet cosmonaut Alexei Leonov made the first EVA when he spent some 10 minutes on the end of a life-line attached to Voskhod 2, with Pavel Belyayev aboard.

NASA administrators looked at a more ambitious Gemini EVA, allowing White to control his movements with the aid of a Hand Held Maneuvering Unit. After a series of meetings, the go-ahead was given on 25 May 1965, just nine days before Gemini 4's launch.

On 3 June 1965 at 10.16 am local time Gemini 4 blasted off from Pad 19 at Cape Canaveral to begin its historic four day mission. The EVA was planned for the second revolution, shortly after the crew were due to rendezvous with the spent second stage of their Titan booster. However, the rendezvous was troublesome and White had problems in preparing his EVA equipment in the cramped confines of the cockpit, prompting McDivitt to postpone the walk until the third revolution.

White opened the hatch 4 h 18 m into the mission and installed a camera to record his activities. He pushed himself out. 'O.K. I'm separating from the spacecraft... O.K. I'm out.' Once safely away from Gemini he fired the gun for the first time, finding that it was an effective means of controlling his movements. Trying to conserve fuel, he corrected his constant tumbling by tugging on the umbilical, noticing Gemini's thrusters firing as McDivitt controlled its altitude. White immediately propelled himself away and began a series of pitch overs and body turns using the gun, finding stopping a very simple task. The propellant soon ran out and left him turning on the tether as Gemini 4 moved over the Gulf of Mexico to begin its fourth orbit. He moved back towards his seat and, after some difficulty, the hatch was closed 4 h 54 m into the mission, giving an EVA time of 36 minutes with the astronaut outside for a total of 21 minutes.

McDivitt and White settled down for the remainder of their four day flight, splashing down 97 h 36 m after launch in the Atlantic Ocean.



Ed White on his EVA. *NASA*

THE GETAWAY SPECIAL PROJECT

By Nicholas Steggall

The advent of the Space Shuttle has permitted many small experiments to be carried into space. The author describes NASA's 'Getaway Special Programme' and the initial batches of experiments.

Introduction

The Getaway Special, 'GAS,' Programme, officially termed the 'Small Self Contained Payloads Programme,' was first offered by NASA in 1976 to anyone who wanted to fly a small experiment aboard the Shuttle, providing that it was of a scientific, research or development nature. The programme is open to industry, educational organisations and domestic and foreign governments for scientific investigation. The aim is to encourage new uses of the space environment and to exploit microgravity. Experiments undertaken using live animals must be conducted humanely.

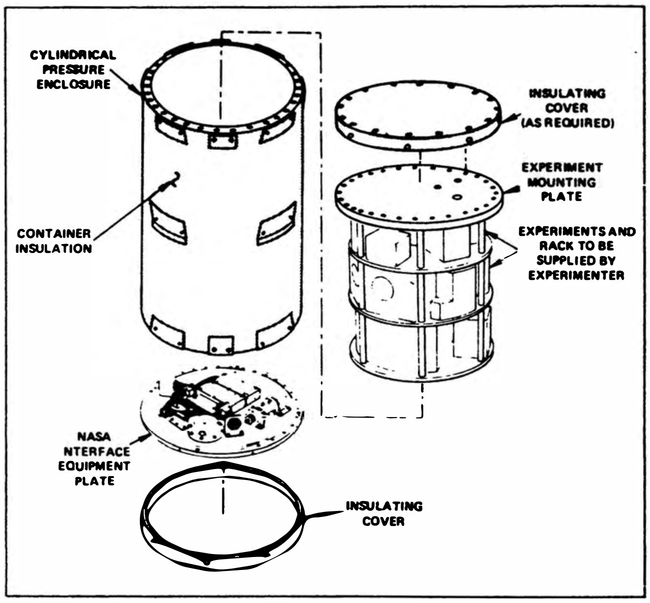
NASA realised the potential of such a programme as they anticipated that the Shuttle would rarely fly with a completely full cargo bay. In 1976 only 10-20 proposals were anticipated but now over 500 GAS places have been booked, with 40% originating from educational institutions.

The GAS Containers

Three sizes of payload can be flown, dictated by volume and corresponding to weight limits. 0.04 m^3 (27 kg, \$3000); 0.07 m^3 (45 kg, \$5000) and 0.14 m^3 (91 kg, \$10,000). The payload must fit inside one of two sizes of cylindrical GAS containers provided by NASA. One houses a 0.14 m^3 payload; the other handles the smaller sizes. The external diameter is 50 cm with a payload height for the 0.14 m^3 version of 72 cm. Apart from that height, the containers are the same.

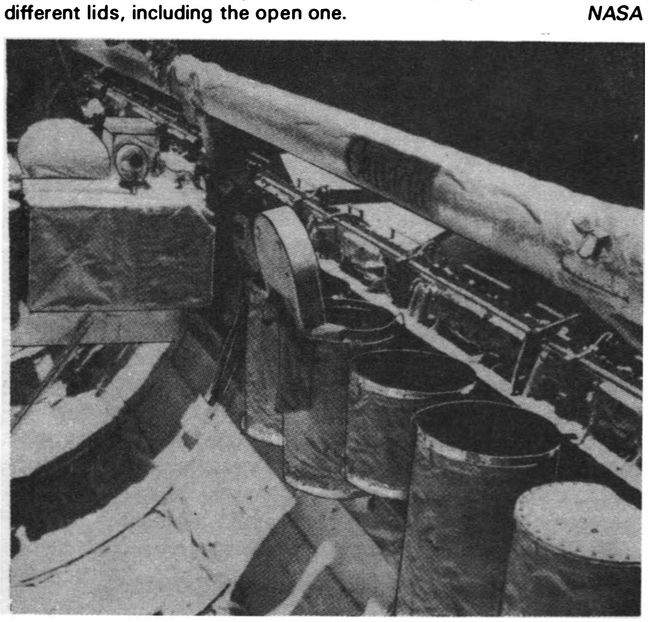
Each carries insulation on its side and bottom for internal temperature control; the primary surface for heat absorption and radiation is the top experiment mounting plate. The covering of this plate can be varied to suit the payload and its requirements. The lid of the container can also be opened and closed by the crew but NASA has to be assured that any outgassing will not contaminate other payloads. Normally the container is sealed to provide a 1 atmosphere internal pressure but it can be vented before flight and kept sealed. A 20 cm window can be provided on the top plate with good transparency in the visible spectrum and into the ultraviolet.

There is a 7.5 cm high space at the bottom of each container to provide room for NASA interface equipment such as control signal relays and vents. A standard bolt hole pattern in the experiment mounting plate is provided for attaching the experiments. The mounting plate and payload is then inserted into the container. To prevent payload vibration, soft bumpers of 'snubbers' at the bottom of the payload structure can be screwed out towards the side of the container, thus preventing movement during launch and landing. The canisters are mounted on the Orbiter's cargo bay wall so that their axes are vertical when the Orbiter lands and horizontal on the launch pad.



The basic GAS canister. *NASA*

GAS canisters in *Challenger*'s payload bay during STS-7. Note the different lids, including the open one. *NASA*



The Experiments

Although NASA provides the container, the experiments and rack have to be supplied by the investigators. NASA will advise the experimenters on the use of space-qualified components such as timers, recorders, sequencers and batteries. The experiments have to be, as the programme name suggests, self contained and therefore provide their own power supply. The only contact with the Orbiter's crew is by a few elementary commands: three on-off signals from the cabin. The commands must be simple to avoid the involvement of complex training, computers and uplink communications.

The experiments might require testing or servicing before they are installed in the Orbiter. This might include insertion of film, electrical continuity tests or even insertion of specimens after the GAS has been placed inside the cargo bay. After the flight a certificate stating that the experiment has been flown on the Shuttle is issued by NASA. Also, to determine the conditions while the experiment was active, a brief summary of the timing and orbital parameters is also provided.

Details of GAS payloads carried on Shuttle flights STS-3 (March 1982) to STS-7 (June 1983) are given opposite.

STS-3

The GAS flown on this mission was the Getaway Special Flight Verification Payload - a 0.14 m^3 test payload canister to record conditions inside the canister during space flight. The GAS carried heat pipe experiments, film samples to record cosmic radiation and instrumentation to record temperature, acceleration, acoustic noise and pressure. These measurements were analysed for future GAS missions.

STS-4

G-0010. This 0.14 m^3 GAS carried nine experiments from the Utah State University.

The fruit fly growth experiment was designed to raise and separate succeeding generations of fruit flies to study the effects of microgravity on their genetic structure.

The brine shrimp growth experiment determined the genetic effects of microgravity on cysts hatched in space. When the experiment was activated the cysts were injected into a saline solution. The growing shrimps were observed *via* a 35 mm motor-driven Nikon camera with a 55 mm micro Nikkor lens for the remainder of the flight.

The aim of the surface tension experiment was to study the shape of a liquid meniscus in weightlessness. It consisted of an aluminium block with several holes filled with solder. During weightlessness the block was heated to allow the solder to flow, assuming a meniscus shape. The block then cooled, 'freezing' the miniscus.

The composite curing experiment completed the curing of a partially cured epoxy resign-graphite composite sample in microgravity. The sample was heated to 163°C for 30 minutes to allow the resin to gel. The microgravity sample was compared with one processed in one-g to determine the quality of 'wetting' between the resin and the graphite fibres and also to test the tensile strength of the sample.

The thermal conductivity experiment was to calculate the thermal conductivity of an oil/water mixture in zero-g. In a one-g environment the mixture separates because of their density difference. In orbit the oil/water were separated and then heated with a platinum wire. The temperature of the heater wire, the mixture and the air around the cylinder were monitored.

The microgravity soldering experiment studied the separation of the flux from solder while soldering in weightlessness. Samples of resin core and coreless solder were melted on four heated copper foils. Afterwards, the solder was analysed to look for trapped pockets of flux in the solder compared with a similar sample processed on Earth.

The 'root growth of duckweed in microgravity' used the 35 mm Nikon camera to photograph the root growth patterns of the duckweed. This investigation centred on the nutrient transport rate played by sieve tubes in the plants roots in response to the force of gravity in Earth-grown specimens. Before the end of the experiment, the plants were injected with a fixing agent. After flight, the flight and control specimens were compared by electron microscopy.

The homogeneous alloy experiment consisted of an aluminium chamber containing a powered bismuth-tin mixture which was heated in orbit, allowing alloying to take place. The chamber then cooled and was returned for analysis.

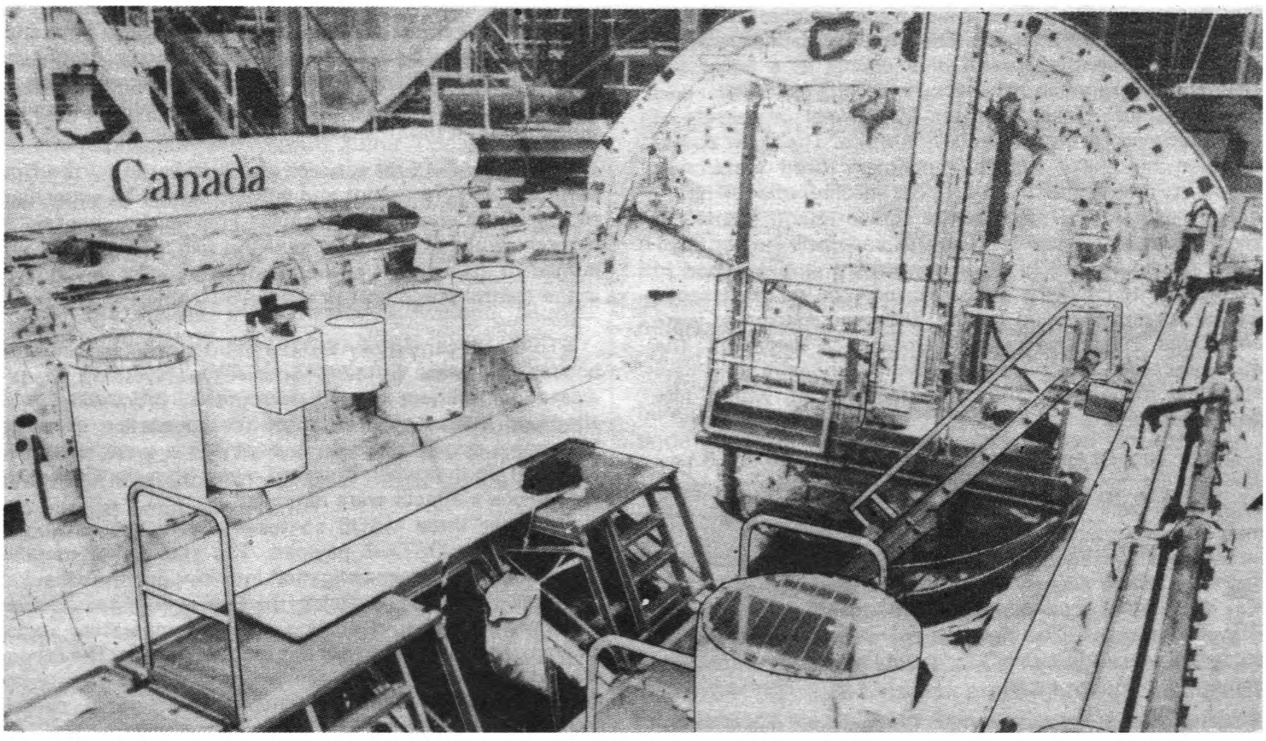
The aim of the algal microgravity experiment was to monitor the growth rate of Chlorella vulgaris (a unicellular green algae) in microgravity. When activated, a freeze-dried sample of algae was injected into a medium-filled growth chamber. The culture's optical density and temperature were measured during the experiment. Near completion, a fixative was added to the chamber to preserve the cells for post-flight analysis.

STS-5

G-0026. This was the first flight of the MAUS (Materialwissenschaftliche Autonome Experimente unter Schwerelosigkeit) of which 25 GAS payloads are planned as part of the material science programme for the German Ministry of Research and Technology (BMFT). DFVLR (Deutsche Forschungs-un Versuchsanstalt fuer Luft-und Raumfahrt) is the project manager.

The payload, constructed in modular form, consists of a standard service system (mounting structure, power supply, experiment control, data acquisition and housekeeping sensors) and experiment instrumentation. This flight was a verification of the standard service system for use on future flights.

The 'Stability of metallic dispersion' experiment used X-rays to penetrate metallic samples to record their appearance in a liquid state periodically on film during mirogravity processing. The sample consisted of two metals (gallium and mercury) which exhibit a miscibility gap in their liquid state. Other metallurgical efforts investigated with this experiment included diffusion, convection, residual Stoke's sedimentation, Marangoni convection (caused by temperature and concentration gradients), Ostwald ripening and



particle growth by supersaturation.

All detailed test objectives and supplementary objectives were met.

STS-6

Three GAS canisters were flown:

G-005. Sponsored by the Japanese newspaper *Asahi Shimbun*, this artificial snow crystal experiment was contained in a 0.14 m^3 canister. Selected from 17,000 proposals, it was proposed by two Japanese high school students, Haruhiko Oda and Toshio Ogawa. The first artificial snow crystals were made by a Japanese physicist Ikichiro Nakaya in 1936, so *Asahi Shimbun* decided to make the world's first snow crystals in space. The experiment consisted of water heated to generate a vapour into a cooled box. Silver iodine was then heated to cause sublimation, the particles serving as nuclei for the snow crystals. The experiment showed no crystals and the GAS was reflown.

G-0381. The seed experiment sponsored by the George W. Park Seed Company used a 0.14 m^3 canister to send 11 kg of seeds into orbit. The aim was to 'see how seeds have to be packaged to withstand space flight.' On return, some were germinated to compare with control seeds kept on Earth during the flight. Some will be stored for 4-5 years, being checked each year to determine storability.

G-0049. The 'Scenic Fast' (Fast meaning Falcon Shuttle Test) was a 0.14 m^3 canister containing six experiments sponsored by the US Air Force Academy cadets in Colorado. The foam metal experiment was to foam metal in a zero-g environment, forming a metallic sponge. The metal beam joiner experiment was to demonstrate that soldering of beams can be accomplished in space. The metal alloy experiment was to determine if tin and lead will combine more uniformaly in zero-g. The metal purification experiment was designed to test the effectiveness of the zone-refining methods of purification in zero-g. The electroplating experiment was designed to determine how evenly a copper rod can be plated in zero-g; and the micro-biology experiment was to test the effects of weightlessness and space radiation on micro-organism development.

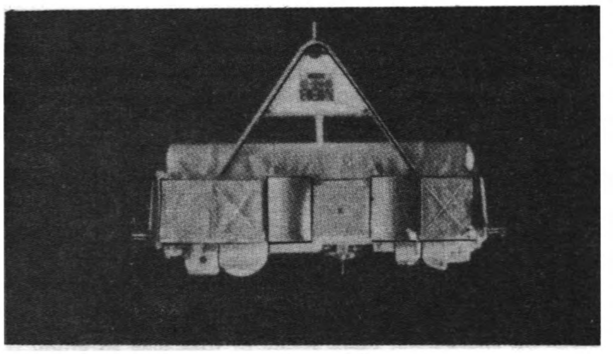
STS-7

Seven GAS canisters were flown, containing 22 experiments.

G-0002. Sponsored by the Kayser Threde company and the Jugend Forscht organisation, the 0.14 m^3 canister contained five experiments selected from a competition of West German high school students. The crystal growth experiment was to observe the growth of a crystal in a liquid salt solution in microgravity. The nickel catalysts experiment was to manufacture nickel catalysts by thermal processing of four specimen cartridges inside a furnace. The plant contamination by heavy metals experiment used watercress shoots to determine the transport mechanisms of heavy metals in plants. Three growth compartments contained seeds, liquids, temperature control and facilities for day/night simulation. The biostack experiment was designed to determine the influence of cosmic radiation on plant seeds (wheat, grain, oats and beans). Different specimens were embedded in containers and exposed to radiation. The microprocessor-sequencer experiment demonstrated a new approach to payload control and sequencing with a low power consumpton.

G-0009. Sponsored by the Purdue University, the 0.07 m^3 canister contained three experiments. The space science experiment was designed to detect nuclear particles that may be encountered in the near-Earth environment and to record their subsequent paths as they penetrate a stack of sensitive plastic sheets. The biological science experiment was designed to observe the germination of sunflower seeds in weightlessness. The fluid dynamics experiment was to study the motion in a very low gravity of a drop of mercury immersed in a clear liquid.

G-0012. Sponsored by the RCA Corporation, this 0.14 m^3 canister contained a whole ant colony in order to see if weightlessness affected the colony's social structure. The ants did not survive the flight. It is believed that purging the atmosphere in the canister with dry air caused the rapid evaporation of moisture from the 'ant-farm,' so causing the ants to dehydrate shortly after being placed in the canister.



SPAS-01 carried the MAUS 1 and 2 payloads.

G-0033. Sponsored by Stephen Spielberg for the Californian Institute of Technology, the 0.14 m^3 canister contained two experiments. The first was an examination of space and microgravity effects ranging from 1/10,000 g to 1/32 g on newly-sprouted radish seeds. The second was an examination of the separation over 96 hours of an oil/water mixture in zero-g. Information gained from this experiment could be used to make improved metal alloys and semiconductors in zero-g.

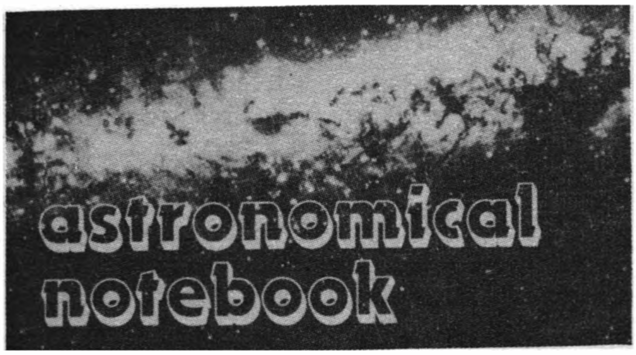
G-0088. Sponsored by Edsyn. Inc., this 0.07 m^3 canister contained nine powered experiments on soldering and desoldering in space with 47 passive experiments to determine the effects of the space environment on the company's standard products. The passive experiments were performed to determine if standard hand tools selected for space repair tasks would be able to work in space. The powered soldering experiments were conducted to determine the physics of solder alloying and possible complications that can arise from debris and fume control in microgravity and in a vacuum.

G-0305. Sponsored jointly by the US Air Force Space Division's Space Test Programme and the Naval Research Laboratory, this 0.14 m^3 canister was the first to use the motorised assembly to open and close the lid. The experiment was an ultraviolet spectrometer designed to observe emissions from the payload bay of *Challenger*. Such an experiment could be used to assess the possible contamination effects on future DoD Shuttle payloads.

G-0345. The 0.14 m^3 canister was sponsored by the Goddard Space Flight Center and NRL. It carried an experiment to assess the effects of the payload bay environment on 12 different types of ultraviolet sensitive film. The canister was purged to the ambient environment by a motor-driven valve in the central purge port of the GAS cover.

STS-7 also carried SPAS-01, a Shuttle pallet satellite that housed two Maus Getaway Special-type systems. Maus 1 was an experiment to test microgravity processing of an alloy and Maus 2 was to study the calculation of critical Marangoni numbers. These two payloads were placed on SPAS-01 so that when it moved away from the Orbiter the spaceplane's effects were removed.

A further three MAUS containers were carried aboard STS-7 on the OSTA-2 payload. The stability of metalllic dispersions was an investigation into low gravity behaviour of metallic dispersions during the heating-up, temperature soaking and repeated cooling into a temperature region where the two liquids do not mix in Earth gravity. The second studied Marangoni (surface tension-driven) convention, while the 'solidifcation front experiment' investigated particle transport mechanisms in multiphase dispersions.



By Prof. John Griffith of Lakehead University, Ontario, Canada.

STELLAR RADIO EMISSIONS

Young pre-main sequence stars will presumably heat the dust surrounding them, so that infrared emission is expected. The typical star of this class is T Tauri, after which the class itself is named. T Tauri stars are sometimes found close to each other, embedded in dark clouds.

About 12 T Tauri stars have detectable radio emission, and when E.D. Feigelson and T. Montmerle studied the Rho Ophiuchi star formation cloud using the NRAO Very Large Array, they detected an extremely variable radio star ('An extremely variable radio star in the Rho Ophiuchi cloud,' E.D. Feigelson and T. Montmerle, *Astrophysical Journal Letters*, **289**, L19-L23, 1985).

X-ray emission from such stars has been taken as giving evidence for powerful stellar flares, which should also generate non-thermal radio emission, highly variable on time scales of hours or even minutes. The discovery reinforces the evidence that pre-main sequence stars are characterised by extremely high levels of magnetically-induced surface activity. In the cloud there may be as many as 11 other radio emitting pre-main sequence stars.

UNOBSERVED MATTER

After fitting various Galaxy models to the vicinity of the Sun, it is predicted that about half the mass in the solar vicinity must be in the form of unobserved matter. It might be in the form of brown dwarfs (stars that are not massive enough to initiate hydrogen fusion), and the nearest one is probably between 0.2 and 1 pc away with proper motion between 1 and 5 arc seconds per year. Such remarkable objects might have been detected by the Infra Red Astronomical Satellite. In the form of clouds, the density would be about 20 solar masses per cubic parsec.

J.N. Bahcall of the Institute for Advanced Study (Princeton), writing in 'K giants and the total amount of matter near the Sun,' *Astrophysical Journal*, **287**, 926-944, 1984, uses the motion of the disc K giants as tracers of the unseen material. Combining observed velocities with 28 different galaxy models leads to the conclusion that about half the disc material near the positions of the Sun has not yet been observed.

REDSHIFT DIFFERENTIALS

The long-standing controversy over whether the redshifts of some galaxies and quasars are entirely of Doppler origin and the problem of the 'missing mass' are both addressed by G.G. Byrd of the University of Alabama and M.J. Valtonen of the University of Turku in 'Origin of redshift differentials in galaxy groups,' *Astrophysical Journal*, **289**, 535-539, 1985.

The redshift controversy rests partially on evidence that an excessive number of companion galaxies in small groups have a larger redshift than the brightest member, whereas one would expect an equal number of positive and negative redshifts relative to the primary galaxy. The authors show that most systems are not gravitationally bound units and hence the problem of sufficient mass being present to produce a bound system is not valid.

THE RINGS OF URANUS

The present concept of the rings of Uranus is that of nine sharp-edged ringlets. The ring particles follow inclined, eccentric ellipses that precess due to the gravitational field of Uranus. As particle collisions would broaden narrow rings in a time much shorter than the age of the Solar System, the system of rings either formed recently or is prevented from spreading. With no apparent evidence for recent formation and with no rings showing a tendency to broaden, it is assumed that the rings are confined by forces produced by nearby satellites, as is the case in the Voyager discovery of two satellites 'shepherding' the F ring of Saturn. No such satellites have been observed. The ring particles themselves appear to range from 0.1-10 mm. J.L. Elliot, R.G. French, K.J. Meeds of the Massachusetts Institute of Technology, writing in 'Structure of the Uranian rings. I. Square-well models and particle-size constraints,' *Astronomical Journal*, **89**, 1587-1603, 1984 commence an investigation of possible orbit perturbations by shepherd satellites by instigating an analysis of the occultation profiles of the rings. This would enable comparisons to be made of ring structure and kinematics with dynamical models. For instance there appears to be a longitudinal clumping of ring material, which may be due to longitudinal waves excited by shepherding satellites.

SUPERNOVA REMNANTS

The evolution of supernova remnants powered by the central pulsar has been considered by several authors. After the supernova explosion has disrupted the star, with the core imploding to form a pulsar, it is expected that a strong radio emission, lasting for a time of the order of magnitude of the initial slowing-down time scale of the pulsar, would be followed by a gradual decay.

Now that there are several galactic remnants resembling the Crab Nebula, probably driven by a central, undetected, pulsar (termed plerions - see Weiler, K.W. in I.A.U. Symposium 101, *Supernova Remnants*, Reidel, p.299, 1983) the interest in the study of pulsar-driven supernova remnants has increased.

R. Bandiero of the European Southern Observatory, F. Pacini of the Arcetri Astrophyisical Observatory and M. Salvati of the Instituto di Astrofisicia Spaziale, in 'The evolution of nonthermal supernova remnants. II. Can radio supernovae become plerions?,' *Astrophsycial Journal*, **285**, 134-140, 1984, use our present knowledge of pulsar electrodynamics to establish a plausible link between radio supernovae and plerions.

Several extragalactic supernovae have been detected

The central section of the Veil Nebula (NGC 6979) in Cygnus. *Kitt Peak National Observatory*

in the radio band some time after the optical outburst. The authors give a table of the properties of the five known radio supernovae, where the presence of a central pulsar is indeed present, the authors examine the consequences of the circum-pulsar non-thermal bubble, which evolves into the plerion. Their model is chosen to fit the radio data, but does not agree with the high-frequency emission.

STAR FORMATION

Stars form in molecular clouds but, as a consequence of the heavy obscuration, it is difficult to observe the initial stages of stellar formation in optical wavelengths. Using radio wavelengths, the flux from the associated HII regions may be observed and the Lyman alpha output obtained. From this the spectral type and luminosity of the ionizing stars may be obtained. V.A. Hughes of Queens University (Canada) and J.G.A. Wouterloot of Sterrwacht, Leiden used both the Westerbork Synthesis Radio telescope and the National Radio Astronomy Observatory's Very Large Array to observe the molecular cloud Cepheus A. Their work is reported in 'The star-forming region in Cepheus A,' *Astrophysical Journal* **276,** 204-210, 1984, where they describe a cluster of about 14 compact HII regions contributing to the total radio flux from the eastern source of Cep A. The radio peak is displaced from the infrared peak, where a number of pre-main sequence objects, incapable of ionizing their surroundings, appear to exist.

The formation and elongation of the HII regions is along a line and the authors propose that the collapsing cloud led to a prolate spheriod with the magnetic field aligned along the axis. A field of 3.5 milligauss has previously been reported; such a field could contain various HII regions. There are two strings of HII regions, each about 0.1 pc long. If the stars are equivalent to main sequence stars, the 14 regions can each be attributed to a B3 star, of age around 1000 yrs, separated in some cases by as little as 1000 AU. Binary stars are predicted, with some stars coalescing into more massive stars. Further star formation is expected.

STELLAR MAGNETIC FIELDS

Magnetic fields on the surfaces of G, K and M stars have been inferred from such indirect evidence as observations of stellar chromospheres, coronae, star spots and stellar flares. The direct measurement of field strengths may be undertaken using the Zeeman splitting of spectrum lines, where single spectral lines become broadened or split into two distinct lines in the presence of a magnetic field.

H.M. Marcy of Lick Observatory, writing in the *Astrophyscial Journal* **276,** 286-304, 1984, in a paper entitled "Observations of magnetic fields on solar-type stars" reports on such observations of 29 G and K main sequence stars with 19 positive detections. Many of the measured stars have field strengths under the detectability limit of 500-1000 gauses and the author notes that the field on the Sun is too weak to be detectable from the average distance of the measured stars. Field strengths range from about 600 to 300 gauss, comparable to the solar magnetic field.

The author searched for correlations between the magnetic field measurements and other stellar characteristics, finding evidence that large fractions of the surface of active main-sequence stars are covered by magnetic fields. Spectral type and rotational period do not appear to be related to magnetic field strength but the fields tends to be higher in K dwarfs than in G dwarfs with, however, no systematic difference evident. Chromospheric emission in the CaII H and K lines varies roughly as the square root of the magnetic field strength and as the square of the effective temperature, consistent with predictions. The magnetic fields are variable on time scales as short as one day and the surface fields are apparently not confined to equatorial regions as is the case for the Sun.

SALYUT MISSION REPORT

By Neville Kidger

The expected reoccupation of Salyut 7 following the departure of Kizim, Solovyov and Atkov did not materialise. It appears that the station has malfunctioned and will not be used again.

A Long Hiatus

Following the successful conclusion of the Mayaks 237-day space flight on the Salyut 7 space station in 1984, it was anticipated that others would follow. During the hiatus between the flights several interesting points about the long stay were revealed in the Western media. It was reported, for example, that Dr. Atkov had the authority to abort the flight at any stage if he noted a significant deterioration in the health of the crew. It was noted that 87 days had been devoted to medical examinations involving a total of 317 sessions. It was also claimed that all future crews on a long-duration Salyut 7 mission would include a medical doctor, that there would be no more international flights to the Salyut stations and that a new Salyut 7 flight was in preparation with the commander being a former Salyut resident.

Nikolai Rukavishnikov was reported as saying, in late 1984, that an all-woman crew was in training for a future Salyut mission. Some Western analysts expected this flight to be a short duration one with Svetlana Savitskaya as commander. The woman cosmonaut herself was reported in late 1984 as saying that 10 women were now in training for space flights.

Medical Report by Atkov

On 25 February 1985 it was reported that Dr. Atkov had made a significant finding during the 237-day flight. As on previous long duration flights, the Mayak team had performed studies of the calcium content of their bones. It is feared that loss of calcium, and thus weakening of the bones, will be the limiting factor in the duration of space missions.

However, Atkov, during the Membrane experiment, conducted studies at cellular level of calcium in the bones. He found that if the cosmonauts took a 'certain preparation, anti-oxidant,' their calcium metabolism at the cell membrane level is not disturbed in the slightest.' The finding was described by the Soviets as of considerable value for treatment of certain conditions on the ground, too, since a whole series of diseases affects the function of calcium transport through the membrane. The drugs used in space could work equally well on Earth, the Soviets said.

Atkov himself said that there was 'practically no time limit to space missions, given appropriate on-board equipment for the spacemen to keep fit and the right training procedures.'

Salyut 7 Flight Over?

On 19 December 1984 Tass reported that Salyut 7 was in an orbit of 366 x 387 km with a period of 91.8 minutes and an inclination of 51.6°. By 0900 GMT on that day the station had made some 15,407 orbits and was in operating automatically. Tests were being conducted 'in accordance with the planned programme' and devices for monitoring micrometeorites were still

Was Savitskaya intended to command an all-female crew to Salyut 7? She is seen here with Kizim aboard the station. *Novosti*

operation. On 31 December 1984, on the Radio Moscow World Service, Boris Belitski told listeners that Salyut 7 was still in orbit and 'still has plenty of life in it. It has now been functioning in orbit for two years and eight months and its on-board systems are reported to be in good shape. So I think that in 1985 we can expect plenty more activity aboard Salyut 7.'

On 25 January 1985 the Soviets reported that Salyut 7 was continuing its flight with all its systems functioning normally. 'Optimum conditions' were being maintained in the working areas and the station was ready to accept a regular' crew.

No launches were made, however, and the next statement came from Tass on 1 March. The Soviet agency noted that Salyut had been in orbit for 34 months and that the information returned from it was being processed. Tass gave a brief run-down on the flights to the station and concluded:

> 'In view of the fact that the planned programme of work aboard the Salyut 7 orbital station has been completely fulfilled, at present the station is mothballed and continues its flight in an automatic regime.'

The short statement was interpreted by some analysts as a final one for the station. If that was correct then the Soviets would de-orbit the station over the Pacific Ocean.

Future Directions

On 26 January, Academician Boris Paton, whose institute had developed the URI tool used on the 25 July 1984 EVA of Svetlana Savitskaya, said that new equipment, to be used to assemble large space structures, had been built. 'The time when robots will be serving as welders in outer space is not too distant,' he said. 'They will assemble in orbit big production complexes with plants for obtaining semi-conducting materials, research laboratories and hot houses (greenhouses).'

The statement was one of many made early in 1985 about the future direction of the Soviet programme. Vladimir Shatalov had written that by the year 2000 research and production complexes would be working permanently in orbit. He said he would not be surprised to see them in work sooner than the date he gave. The complexes would consist of 'docked blocks and modules,' he said.

In another statement, Aleksei Leonov said that EVAs would be 'inconceivable' in the new space 'settlements.' He noted that the modular space complexes would be 'welded directly in orbit.' In conclusion, Leonov said that science laboratories and technological plants would be created in space.

FROM THE SECRETARY'S DESK

'History on the Hoof'

This slightly inelegant but descriptive epithet by Gordon Vaeth well described the members of the '55' Club trotting from hanger to hanger at the Paul E. Garber facility in Washington last March, to see renovating work underway on a huge store of artefacts destined for the National Air and Space Museum.

The group - Milt. Rosen, Kurt Stehling, Howard Canney, Ron Wakeford, Saunders Kramer, George James, Frank Winter, myself and, of course, Gordon, represented quite a chunk of space history. The 55 group, incidentally, has only three honorary overseas members *viz:* Les Shepherd, Hermann Oberth and myself, so the opportunity for a get-together was not one to be missed.

The collection of aircraft - experimental, unique and outrageous - was breathtaking. More so were the stores crammed with disassembled masterpieces awaiting reconstruction. It included a number of Goddard rocket engines and parts, vintage 1929-30, along with specimens of German wartime missiles such as the X4, He 293, Natter, Rheintochter and even an Me 163B.

The Goddard artefacts were acquired in 1950 but identification is likely to involve matching them up with the original hundreds of photos in Goddard's notebook. The published *Papers of R.H. Goddard,* even though running to three volumes, only reflect a fraction of the original Goddard documentation.

The National Air and Space Museum, itself, contains two Congreve Rockets, loaned from the collection at the Rotunda, near Woolwich Arsenal. It also has two cutaway rocket engines, the Supersprite and Spectre (BIS members were heavily involved in both) though only one is currently on show.

Frank Winter and the Executive Secretary inspect a stored Goddard rocket.

Good Deeds

It has been put to me that the term *Deeds of Covenant,* to which we refer so earnestly and so often, conveys little to American readers.

Actually, it is a scheme whereby members' annual subscriptions, and any donations, can be charged against UK income tax. The only stipulation is that the member must pay the appropriate sum (i.e. remain a member) for at least five years.

Amounts paid by members are *after* deduction of tax. This enables the Society to reclaim the tax paid in the first place and thus add a very useful addition to our income.

A Cometary Suggestion

M.J. Price, Dept. of Coins and Medals at The British Museum, has drawn my attention to the suggestion recently made that the small crescent accompanying the famous owl on all tetradrachms of Athens from 479 BC onwards (*New Zealand Num. Journ.,* **56,** 1977, 18-21) represents a sickle or 'horned' comet that Pliny (*Nat.Hist.* II.22.90) states as having appeared at the time of the battle of Salamis in 480. He adds that, for various reasons, such an idea would be attractive, but wonders if it would be necessary for such a comet really to be symbolized as a crescent 'moon.'

I tend to doubt it myself, for the crescent Moon was important enough in its own right in ancient times, not least as a time keeper, with a significance for transcending that of infrequent comets. I wonder what readers think?

Woolley Thinking

A reader asked me for a specific reference to the immortal utterance by Richard van der Riet Woolley on his arrival at London Airport on 3 January 1956, to take up the post of Astronomer Royal.

According to A.P. Herbert's *Watch this Space* Dr. Woolley said that the first question put to him was about the possibility of interplanetary travel. His reply was, "I can't answer that" and, when asked "Why not?," he added "because it's utter bilge."

Subsequently, Dr. Woolley is reported to have explained that, when he said 'utter bilge,' he had science fiction very much in mind. Even so, he added "interplanetary travel is, and remains, utter bilge. It remains hideously expensive; the surface of the Moon and planets are so inhospitable to life that there's no question of living on them; the difficulties of setting up a launching station to arrange for a safe return are enormous."

Woolley didn't learn. *The Washington Post* of 11 November 1957 credits him, this time commenting on Sputniks 1 and 2, as saying "The details we have been given about the weights and dimensions are quite incorrect. The satellites are nothing like as large or as heavy as we have been led to be believe" adding, for good measure, "The satellite is little more than a scientific gimmick." He criticised lunar journeys as "Moon madness," warning that "Inevitably, in the early stages, there will be inumerable casualties."

For the benefit of any doubters who remained he concluded, with becoming modesty, "With 1/10th of 1% of the money the Russians must be spending, *I* could make a more useful contribution to science."

In 1960, he exclaimed "There are many important astrophysical observations crying out for attention which would not benefit in the least by being transferred to satellites... it is not too clear just what problems would be served by rocketry..."

If Dr. Woolley had had his way, we would never have seen - to take a few recent examples - Infrared

Astronomical Satellite, International Ultraviolet Explorer, High Energy Astrophysical Observatory, Hubble Space Telescope, Rosat, Extreme Ultraviolet Explorer, and Solar Optical Telescope, let alone Spacelab investigations into solar physics, high energy astrophysics, infrared astronomy and plasma physics, or Giotto, Voyager, Pioneer, Galileo, Ulysses or the Venus Radar Mapper.

Mankind would have been the poorer.

Happy Story

We were delighted to learn the following story concerning Professor Oberth, an Honorary Fellow of the Society and now 90 years old.

It appears that some months ago, at his home in Feucht, Germany, he had the opportunity of holding in his hands a piece of actual Moon rock encased in lucite for handling purposes.

How appropriate it was that this distinguished space pioneer whose works *Die Rakete zu den Planetenraumen* (*The Rocket into Interplanetary Space* - 1923) and *Wege zur Raumschiffahrt* (*Road to Space Travel* - 1929) pointed the way to the stars should actually hold a piece of the Moon, our undoubted stepping-stone to other worlds.

The Low-down on High Down

The account of his involvement with 'Black Arrow' recounted by Charles Tharrett in the May issue under 'In Retrospect,' may well lead to other members submitting further contributions of this nature. Many members have been involved in a variety of space projects. Personal accounts of such involvements, including stories or anecdotes, illustrations and the like could give a full flavour to the text. Some things may not seem so earth shattering now yet, nonetheless, are of great personal interest both to the individuals concerned and to us, hence our invitation.

The text required is not overtly overlong and invariably flows very easily when recounting events in which one was personally involved.

Chinese Astronauts

I was intrigued to see that the Chinese Society of Astronautics also has a publication called *Space Flight,* the front cover of which shows this both in English and in Chinese. The Chinese version of the word looks strange, even occult, to Western eyes, but it is reproduced below to help readers expand their knowledge.

Incidentally, the Chinese version is spelt backwards i.e. the first character is *Flight* and the second character *Space.*

Getaway Special

I was intrigued by a story from Deane Davis referring to a certain Clint Cary who, on returning from a three-day stay on the planet 'Rillispore' in 1963, started to hand out space cards and allocate numbers to the chosen since 'on or about 17 June 1985' a planet called Lycillis Apum will travel to within 13 million miles of the Earth. Since L.A. is about the size of Uranus, its passing will have catastrophic results.

Additional data was added by a Helen Hoagg, who managed to vist a sister planet of Rillispore and reported on the construction of spaceships two miles across.

Clint, who receives messages through colour-telepathy, figures that each spaceship has a ten-million person capacity, quite enough to transport all the recipients of his cards to date.

Cardholders appear to have varying degrees of status. Those with titles of King, Prince or Exhultant Ruler, can also give out cards. Deane, needless to say, ranks as Duke and is thus qualified to fill up one of the space ships on his own. But where on Earth will he store ten million cards meantime?

Heaven-sent

A curious cloud formation the other day - a great circular mist with a large central hole - looking for all the world like a nearby ring nebula, reminded me of the magnificent woodcuts of unusual atmospheric phenomena that once graced books. It prompted the thought that one can see almost anything one wants to in the sky, just by looking long enough.

I've never seen mock suns but I have seen double and triple rainbows, the aurora (looking like a red cloud over London) and single and double halos round the Moon. Lunar halos, incidentally, come in two types. Most snuggle closely to the lunar disc but others form a large circle, perhaps 30-40 degrees across as far as I could judge. I've even seen a square Sun (actually it was more rectangular) caused by a curious cloud formation while 'flaming swords' - in the shape of exploding meteors - are ten a penny.

Even sunspots occasionally become apparent to the casual glance, as reported by the ancient Chinese astronomers. Once, before the war, a large sunspot group in the upper right hand side of the disc gave the early morning reddish Sun a tearful appearance, seen through the haze.

But I've never seen the green flash nor the Gegenschein.

Back Issues of *Spaceflight*

We are always pleased when members send us collections of back issues of *Spaceflight* for which they no longer have space or requirement.

We can always put them to good use. The demand for back issues, particularly from our newer members, remains high and there are many requests to fill from libraries who have lost, damaged or mislaid copies and seek replacements.

SURPLUS LIBRARY BOOKS

We have a number of surplus Library Books and Reports on astronomy and space that are being offered at very low prices. To secure a list of those available, simply send a reply-paid envelope with your request to The British Interplanetary Society, 27/29 South Lambeth Rd, London SW8 1SZ. If you spend £20 or more you may deduct a 10% discount.

Please enclose a 20p stamp and specify if you require the Book List, Technical Report List, or both.

DELUXE CERTIFICATES

Both Fellows and Members may now purchase high-quality certificates suitable for framing. These are 29.5 x 41.5 cm in size, printed in three colours and with the member's name hand-inscribed. They are available for only £5 ($8) post free.

When ordering, please indicate membership grade and allow six weeks for delivery.

SPACE MEETING AT GODDARD

by L.J. Carter

The 19th European Space Symposium was held in conjunction with the 23rd Goddard Memorial Symposium at NASA Goddard Space Flight Center, Greenbelt, Md., USA., from 27-29 March 1985, organised by the American Astronautical Society (AAS) and co-sponsored by our own Society, the AAAF, AIDAA and DGLR. Additionally, cooperation was provided by Eurospace and by four further American organisations concerned with space promotion.

The result was a most worthwhile event. Over 30 papers were presented and a generally high standard reached both in presentation and content. The Programme was not, as one might have expected, overshadowed by American contributions; rather the reverse. The European contributions more than held their own, reflecting the resurgence of interest in space now emerging both in ESA and in National programmes.

The audience, just over 240, represented a good cross-section of both US-Europe involvement in space, as borne out by the chosen theme of 'Europe-US Space Activities. Additionally, there was a strong student participation reflecting, to some degree, the personal encouragement given by President Reagan himself last October to the 'Young Astronaut' programme. Attendance was well sustained throughout the meeting, questioning was close and detailed and the supporting range of activities, which included a Luncheon, Dinner and tour of NASA Goddard, were excellently arranged.

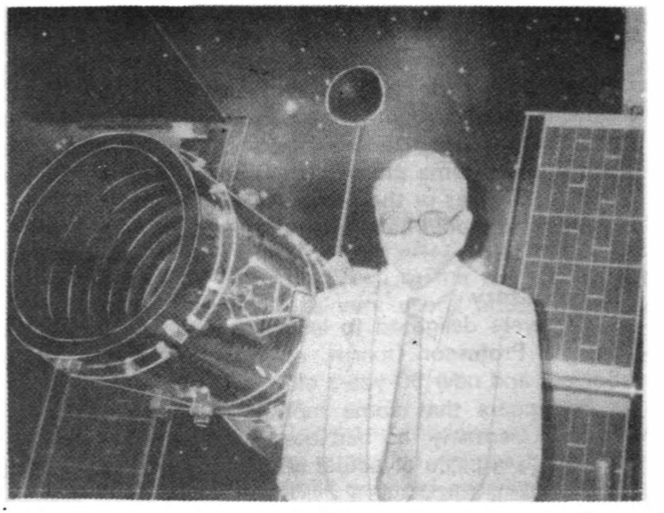
Goddard Tour

Proceedings opened with an afternoon tour of NASA Goddard Space Flight Center on 27 March, which placed particular emphasis on the Tracking and Data and Environmental Test Facilities. Goddard is the major NASA space facility concerned with space and Earth sciences, an interest now being extended to include a focal point for developing Space Station utilisation. The Center occupies a site of 1108 acres and has a total of 27 major buildings. Fourteen are laboratories, seven are support buildings and six are office blocks. It has a workforce of about 6500 people, half of whom come from private industry. The remaining civil service staff includes about 2000 scientists and engineers.

Goddard is not only the nerve centre of NASA's worldwide three million circuit system of instantaneous voice and data circuitry tying together 21 sites of the Space Flight Tracking and Data Network, but is one of the world's largest users of computers. GFSC has prime responsibility for the Delta Launch Vehicle, until recently the most frequently employed NASA rocket, as shown by a Notice Board at the entrance proudly proclaiming 166 successful launchings to date, i.e. a success rate of over 93%.

Technical Sessions

Participants were welcomed by John Quinn, Deputy Director, GSFC, who felt the choice of Goddard most appropriate not only because of its many past international programmes - it was looking forward particularly to the International Solar-Terrestrial Program - but also because of its forthcoming role in servicing platforms for the Space Station. The Space Telescope, a large model of which



Dr. Horace Jacobs in front of the Hubble Space Telescope model.

was displayed in the foyer, was now undergoing integration tests with new studies underway on the differences between first and generation experiments. Whereas in the first generation model reliance had been placed on computers, and little on 'smarts,' it now seems that, even before it flies, major improvements can be made to accommodate greatly expanded possibilities for improving its uses and applications.

The technical sessions fell into four well-defined groups *viz:* National Space Programmes, Space Station and Platform, Cooperative International Programmes and Space Science and Applications Programme.

Five UK papers were presented, all of which will be published in full in *JBIS*.

The first of these was on the massive communications satellite, Olympus, prepared by BAe under a contract by ESA in 1982 and with a launch date of 1987. Olympus will be the world's most powerful multi-purpose advanced spacecraft platform, with plenty of room for subsequent exploitation to meet the needs of the 1990's. In other words, development is not limited by the capacity of Ariane 3. In fact, Ariane 4 will be available *before* the first spacecraft launch, so opportunities for further development exist already.

The keynote address was provided by Dr. Owen K. Garriott, an astronaut from NASA Johnson Space Center. Owen is scheduled to fly later this year and much enjoys his new job as programme scientist for the Space Station. His keynote address was about space pioneers, with emphasis on the work of the late Dr. Goddard who, while a loner and not communicating overmuch with the outside world, was in almost weekly contact with his Patent Attorney. Actually, over 200 patents were granted in his name, though many were filed posthumously by his wife. On a more personal note, he added that it takes a few days to get adapted to space but it is a very pleasant place to work in. He anticipated that the operational procedures on a Space Station will prove to be entirely different from the Shuttle and it will certainly prove necessary to maintain an ample exercise balance to prevent calcium loss (bone dimineralisation).

Four papers that provided Space Station overviews from the American, Canadian, French and Japanese viewpoints were followed by many others which illustrated European interest in particular segments e.g. manned and unmanned Space Station elements, space research links with NASA, involvement in the life sciences and global monitoring of Earth observations.

The US overview, by Captain R.F. Freitag, gave some interesting information about the Space Station users

data base. This summarised into the following number of proposals:

Space Science: 162
Space Technology: 105
Commercial: 65

These proposals are to be spread over an activation period of two-three years but far too many appear to depend on EVAs, so will have to be pruned to take account of a heavy reliance on automation and robotics instead. About 80-85% of all missions were satisfied with the proposed 28.5 degree orbit. Actually, the utilisation of the Space Station is still wide open for participation by other nations or commercial organisations, with final selection yet to be made.

The Space Station is currently in Phase B i.e. a definition study period concerned with determining its final form. Phase B leaves open the possibility of further variations in concept so the final result could differ substantially from present concepts. Phase B, incidentally, is not a joint integrated activity between America and its European and other partners, but a series of parallel studies that will be integrated a year or two from now. The emphasis is on an *evolutionary* approach i.e. by including the capability to replicate and add on to create new opportunities.

The present situation is that the scientific community in America, largely, is fully committed to the Space Station concept and convinced that it is an area whereby space science will develop. Europe, too, has formed a Science User's Committee. The US Department of Defense interest seems small but commercial interest is growing.

One of many problems still to be resolved is the difference between an international Space Station and one with international participation. They both sound alike but are substantially different: for example, which body of law will apply?

Geoff Horrit provided a paper on the Eurostar platform. This has been designed jointly by BAe and Matra as a middle-of-the-range 200-300 kg platform with a 10 year lifetime to meet a variety of direct broadcast TV and similar requirements. Its basic design ensures full compatability with both the Ariane 4 and the Space Shuttle/PAM DII launch vehicles. Most of the development programme will be completed by the end of this year.

Two further papers from British Aerospace also proved of considerable interest. The first concerned requirements for multi-user space platforms maintained in-orbit by periodic visits by the Space Shuttle. Incidentally, Europe has been looking into the potential of low-orbit permanent platforms on its own account for some time now. Both the French Solaris and the German Euros called for unmanned, robot-tended platforms - principally as materials processing facilities - and both were included in the ESA long-term programme studies. British Aerospace involvement has stemmed from the premise that Europe should not only be a user of US Space Station facilities but should also contribute elements attractive to many peripheral users prepared to share the same platform. Earth observation users, for example, already see a demand for clusters of instruments in polar orbit, perhaps mixing experimental and operational packages on the same craft.

The platform concept represents a novel way of conducting operations in space and could easily develop into an important new area. The current situation is that BAe expect to begin phase B studies on the European space platform as part of the ESA Columbus programme, starting in May 1985 and, if found attractive, will follow with Phases C/D in 1987 and an initial launch in 1992-3.

The second paper of considerable interest was on Hotol - a Horizontal Take-off and Landing Satellite Launcher or aerospace plane. When unveiled at the SBAC show last year, interest proved so great that many couldn't get near the stand. Peter Conchie, the author of the paper and a BIS Fellow, was then among those escorting both the Prime Minister, the Rt. Hon. Margaret Thatcher and her husband, around the stand. The Prime Minister expressed great interest. Press interest, too, was very great, centring on how much Hotol would cost and whether the UK could undertake it alone.

The basis for Hotol stems from the fact that demand for satellite communications is still increasing steadily and is certain to continue though it will become less easy to predict rates of growth as the manned station appears and commercial remote sensing aspects are more fully developed. It is certain, however, that the market will depend on launch costs. The semi-reusable Shuttle was a major attempt to reduce costs significantly but has not lived up to expectations with the result that the Ariane launchers now compete successfully with it. By the end of the century, however, improved Shuttles will certainly bring costs down so, if Europe is to continue to compete, and so manufacture and sell communication satellites, a successor to Ariane must be produced that will match the enhanced Shuttles in cost-effectiveness.

Thus arose the proposal for an expendable and semi-reusable aerospace plane, first announced in August 1984. After studying more than 30 different configurations, the conclusion was reached that reusable launcher should take the form of a single vehicle with a high operating rate and rapid turnround. Air-breathing propulsion would reduce engine thrust-to-weight ratio and wings provide a good trade-off with propulsion, thus giving a better initial trajectory. The result was a hybrid engine using atmospheric oxygen and on-board liquid oxygen to accelerate the vehicle to high speed in the lower regions of the atmosphere. The proposal was similar to others considered many times before e.g. in 1963 when the Society held a one-day meeting devoted solely to the theme of the 'Aerospace Vehicles' though, at that time, technical difficulties seemed insuperable.

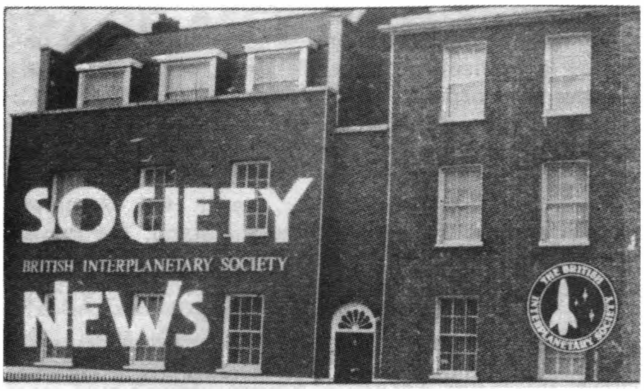
The vehicle that has now emerged is part-spacecraft and part-aircraft with a brand new propulsive system, weighing about 200 tons i.e. about the same size as Concorde, and with a 50 ton return weight. It is a concept that builds very largely on existing technology and contains many inbuilt safety margins.

Social Events

The Symposium proved a first-rate opportunity for private discussions but, even so, the three day duration proved so short that one was more conscious of what one had failed to do rather than what had been accomplished. Fortunately, the Luncheon and Dinner afforded two excellent occasions to relax. The speaker at the Luncheon was Roy Gibson, formerly Director-General of the European Space Agency, who spoke on the long road still to be traversed by America and its partners in the Space Station project. Although so many heartening developments had taken place in recent months, many pitfalls lay ahead.

The end of the Symposium was marked by the Goddard Memorial Dinner. This was actually a separate function sponsored by the National Space Club but held so close to the conclusion of the European Space Symposium that it was attended by most of the Symposium participants.

After welcoming speeches, in which grateful acknowledgement was paid to the support from co-sponsoring bodies, an excellent meal was provided followed by a number of presentations.



SPACE STATION MEETING

The Society's one-day Symposium on 'Space Stations' was held at headquarters on 17 April last. It proved a great success, with every place taken. A range of speakers from Europe and the US provided wide-ranging viewpoints on this next major step in space exploitation.

The US is keen on securing international cooperation in this major undertaking and would be pleased to see an extensive involvement from Europe, and from the UK in particular. Jack Leeming, on behalf of the Department of Trade and Industry pointed out that the Ministerial Conference held in Rome last January was a landmark, not to say a watershed, in the European and UK space story. The strong UK position adopted had acted as a signal to UK industry and its potential user community alike. Tremendous opportunities were now possible with the British Aerospace 'Space Platform' forming a major UK contribution to the programme which would help to strengthen the Remote Sensing commitment already developed in this country. He added, however, that attention given to possibilities for working in microgravity tended to be somewhat less in the UK than, for example, in West Germany. This underlined the need for Space Station users to be intimately involved in shaping the programme at an early stage.

Roy Gibson, former Director-General of ESA, thought that the Space Station was now heading towards becoming a *truly* international project and believed that each European member state should now put its full weight behind ESA to negotiate with NASA, adopting a "a policy of aggressive cooperation." The polar platform could prove to be the most popular part of the system but the UK continued to express interest in the main section, the "core."

The next two years are critical: no one European nation should impose its national aims on a real and true international project. Even the initial Space Station is vitally important. It will affect how we conduct and use space enterprises for the next two or three decades.

LIBRARY UPDATE

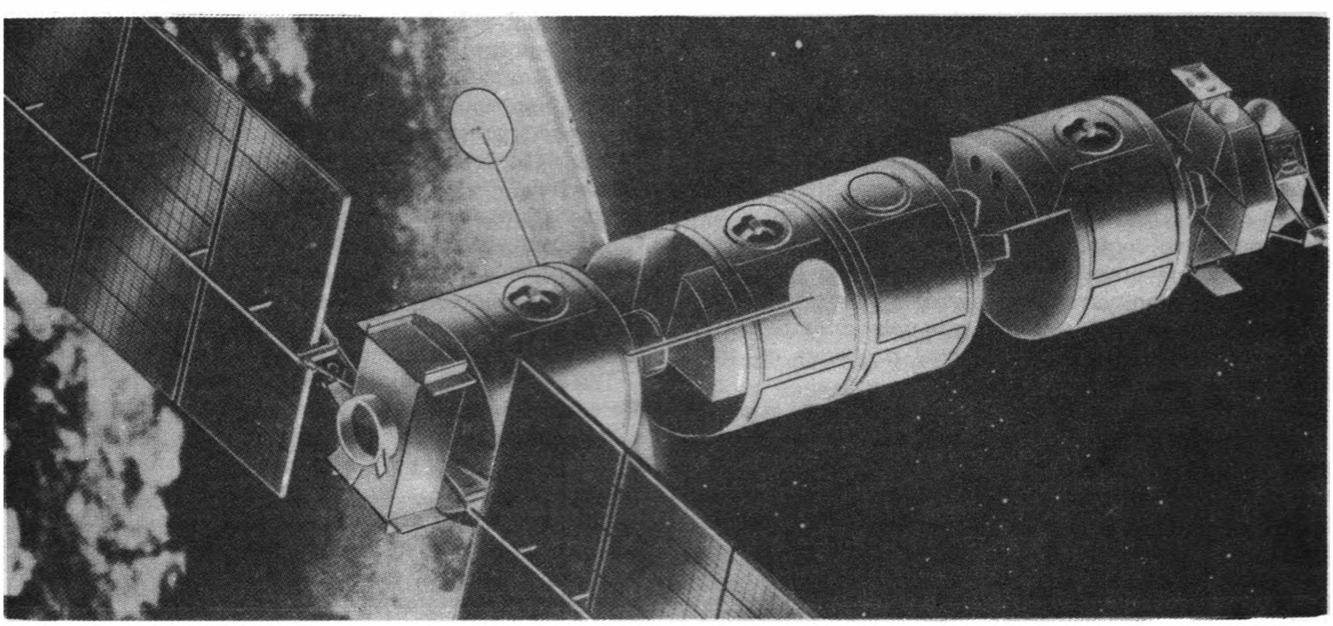
In December 1959 the Council's attention was drawn to the lack of a suitable library. There was no room in our small offices for a library or reading room, nor was there even a volunteer Librarian. The result was that those who came to look at books brought the office to a standstill for an hour or two at a time, posed problems with meetings and interviews and generally resulted in a feeling that limited staff time had been used fully and essential work left undone.

Consequently, it was agreed that the Society should establish a Specialised Space Library in our next HQ. The work was deputed to the Executive Secretary who was required to secure as much support from members and others as was practical in order to bring this into being at the earliest possible moment.

An indication of the success achieved to date, even if our collection is now growing only slowly, is shown by the following details of our acquisitions, though our plans have since been augmented by a proposal that the Society should establish a number of special collections, all of which would be suitable for subsequent display. A list detailing these later areas of interest appeared in *Spaceflight* for April 1985 (p.191).

	At 31.2.1985	*At 19.7.84*
Books	2530	2440
Reports	4650	4496
	7180	6936

An artist's concept of Columbus.



One of the items we have listed where members may be able to help concerns the small collections we are building up on books, reports and documentation on Solar eclipses and transits of Mercury and Venus. We hope that some members have material they are willing to donate.

Books and Reports

Our collection of current volumes is substantially complete though attempts to retrace our steps to secure volumes from earlier decades have not been wholly successful. A list of items we are seeking for our Library appeared under the heading 'Desiderata' on p.185 of the April 1985 issue of *Spaceflight.* Nonetheless, many members have continued to provide us with books in which the Society has great interest. Sylvia Lundy for example, sent a copy of *Modern Observational Techniques for Comets,* Martin Lifgren forwarded a copy of *Life in Space,* Andrew Lintern-Ball sent *A Source Book in Astronomy and Astrophysics 1900-1975,* and P.L. Halifax a copy of *Fundamental Astrometry.* Fred Durant added *Worlds Beyond: The Art of Chesley Bonestell* and Charles Sheffield a copy of his own book on *Space Careers.*

Two authors were particularly kind in connection with books on our special list. Henry S.F. Cooper Jnr., for example said, 'When the BIS calls, who can refuse?' and sent three of his books that we badly needed. Shirley Thomas, whose eight volumes of 'Man In Space' were particularly sought after, also sent copies of the missing volumes and thus enabled us to complete our set.

We are particularly pleased to acknowledge the gifts from all these donors but must especially mention Harold S. Bates who, in view of his advancing years, decided to give to the Society first selection from all the books in his Library prior to his death.

We are very pleased indeed to acknowledge a substantial collection of NASA reports, through the courtesy of Dr. Burt Edelson, and another copy of SP-474 on the *Flight of Voyager 1 and 2* from Dale Kornfeld. We send our thanks to these donors also.

Space First Day Covers

Our collection of First Day Covers relating to astronomy and space continues to grow, *albeit* slowly. The good offices of Lester Winick helped us secure a cover honouring the rocket post pioneer Friedrich Schmiedl, Alfred Persson sent us one on Viking with the compliments of Saab-Space and Nicholas Hey exchanged our rather tatty 150th Royal Astronomical Society Anniversary cover for one in better condition. Andrew Benkovich provided a first day of issue cover commemorating the Canadian Astronaut Program and, indirectly, the first flight of a Canadian into space.

J.M. Lewis, while not having any First Day Covers, waded in with a substantial collection of space stamps. Keith Wright, as ever, kept a watching brief on FDCs issued *via* ESA and covered this aspect of our collection excellently.

Decals

Decals remain hard to get. They are plentiful enough but most members do not think of us as potential recipients so we end up with rather fewer that one might expect.

Space Cards

Following the article on the Society's collection on space cards that appeared in *Space Education,* October 1984 p.368, we received a set of Space Shuttle trading cards kindly donated by Odyssey magazine. The relative paucity of other responses tends to confirm that such items must be rarer than we thought.

Space Medallions

The Society's collection of space medallions, on the other hand, continued to grow apace. Eight Apollo medallions were donated by Stewart Greenwood, many more from Bill McLaughlin and an Arianespace medallion from Rex Turner. The long-lost medallion issued by Boots the Chemist turned up as a gift from Phil Clark while Jim James added a gift from the Soviet exhibition in Australia. Bruce Adkins searched out a medal commemorating the 19th century work of Norman Lockyer on solar eclipses, and well-nigh promised to dedicate the rest of his life to finding similar items on our behalf. Following a visit to the USSR, Don Riley produced a number of specimens of roubles showing a portrait of Valentina Tereshkova and medallions to commemorate Yuri Gagarin while, finally, Fred Durant provided an excellent selection of USSR lapel-type space badges.

We now possess a total of almost 100 space medallions and are extremely grateful for all those who supported what is now beginning to emerge as a worthwhile collection.

Archival Papers

It isn't very often that we obtain original or, indeed, photocopies of oldish material but Wayne Lewis sent a photocopy of 'The Apparition of Halley's Comet in 1909-1911' while Alex Geddes supplied not only some original letters from Valier and von Opel but also some from Verschoyle. All this material has since been written up for *Spaceflight.* Even closer to home, D.V. Daniels produced a letter written by the late Val Cleaver, a former Chairman of the Society, to add to our stocks.

Sound and Visuals

A range of material arrived under this heading. Geoff Richards provided some drawings of the Daedalus vehicle prepared by Dave Mussell, Bill McLaughlin provided a fine set of slides and a number of films arrived from Captain James London with one further film from Thomas O'Neill. A number of radio tapes arrived through the good offices of Dr. Burt Edelson and a few more from Roger Wheeler.

Does any member know where we can get the words and music for several songs issued in connection with the Apollo landings? We have no other information about them apart from the certain knowledge that they existed.

Models

Douglas Arnold produced a fine Shuttle tile for exhibition in a Library display case, along with a useful collection of genuine Apollo/Skylab space food containers, with contents! A number of industrial firms contributed models for display on the tops of our Library stacks while Fred Durant added three more, all excellent Shuttle models, thus bringing the total so far to 17 such models, with space left for another 22.

OUR HQ IN NEW CONSERVATION AREA

We have been advised by the Local Council that the whole of the Society's offices now form part of the new Conservation Area in the district and that no alterations, improvements or changes of any sort can henceforth be made without permission.

SATELLITE DIGEST -185

Robert D. Christy

Continued from the June issue

A monthly listing of satellite and spacecraft launches compiled from open sources.

The heading to each launch gives the name of the satellites, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

GEOSAT 1985-21A, 15595

Launched: 0200, 13 Mar 1985 from Vandenberg AFB by Atlas F.
Spacecraft data: Size and shape not available, but the mass is 635 kg.
Mission: Combined payload providing geodetic data about the southern hemisphere and the north Pacific Ocean in particular, and mapping the ocean surface of the Earth. The data returned are intended to make up for that lost as a result of the premature shutdown of Seasat (1978-64A). Geosat is operated by the US Navy.
Orbit: 760 x 817 km, 100.67 min, 108.05°.

COSMOS 1634 1985-22A, 15597

Launched: 0110, 14 Mar 1985 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a drum-shaped solar array with length and diameter both about 2 m. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 960 x 1011 km, 104.87 min, 82.94°.

COSMOS 1635-1642 1985-23A-H, 15617-15624

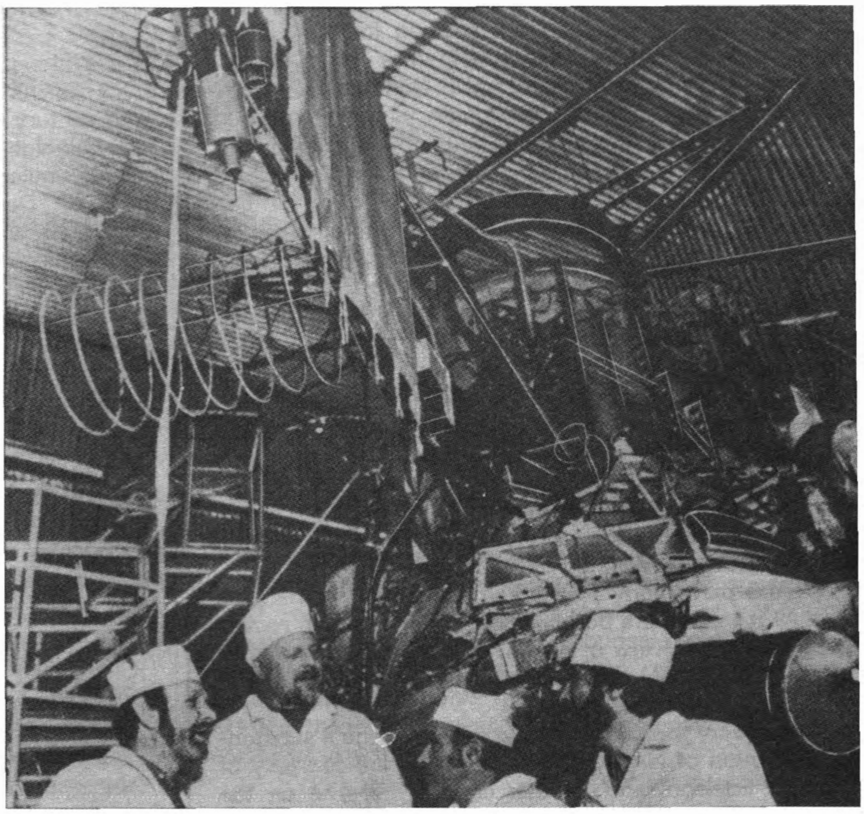
Launched: 0010, 20 Mar 1985 from Plesetsk by C-1.
Spacecraft data: Probably spheroidal in shape, about 1 m long and 0.8 m diameter and with mass approx 40 kg.
Mission: Single launch of eight satellites to provide tactical communications between troops and units in the field.
Orbit: 1400 x 1478 km, 114.68 min, 74.06° (lowest), and 1474 x 1514 km, 115.88 min, 74.06° (highest).

EKRAN 14 1985-24A, 15626

Launched: 0500, 22 Mar 1985 from Tyuratam by D-1-E.
Spacecraft data: Cylinder with a pair of boom-mounted solar panels, and a flat aerial array at one end. Length 5 m, diameter 2 m and mass in orbit around 2000 kg.
Mission: To transmit programme of USSR Central Television to collective receiving aerials serving remote communities within the USSR.
Orbit: Geosynchronous above 99°E longitude.

INTELSAT 5A (F-10) 1985-25A, 15629

Launched: 2358*, 22 Mar 1985 from Cape Canaveral AFB by Atlas Centaur.
Spacecraft data: Box-shaped body, 1.66 x 2.10 x 1.77 m with attached 4 m aerial mast and a 15.9 m span solar array. The mass before apogee boost motor firing was 2013 kg, reducing to 1098 kg on depletion of fuel. The vehicle is three axis stabilised using momentum wheels, and station keeping is by the use of gas thrusters.
Mission: Communications satellite operating at C-band (6 GHz uplink and 4 GHz downlink) and Ku-band (14 GHz uplink, 11 GHz downlink). Traffic carrying capacity has been increased by 25% over that of Intelsat 5, to the equivalent of 15,000 telephone channels.
Orbit: Geosynchronous above the Atlantic Ocean.



By about the time this issue of *Spaceflight* is published, the two Soviet Vega Venus/Halley probes are due to release landers and balloons into the Venusian atmosphere. The picture shows one of the main carrier craft in preparation; right appears to be the dual cylinders of the scanning camera platform. No Venus capsule is visible at top. Novosti

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COSMOS 1643 1985-26A, 15634

Launched: 1000, 25 Mar 1985 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit, and a supplementary package of instruments at the forward end. Length about 6 m, diameter (max) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaissance.
Orbit: 183 x 276 km, 89.09 min, 64.77° manoeuvrable.

COSMOS 1644 1985-27A, 15636

Launched: 0840, 3 April 1985 from Tyuratam by A-2.
Spacecraft data: As Cosmos 1643.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 349 x 415 km, 92.22 min, 70.34°.

CORRECTIONS/UPDATES:

In the middle of 1984, US military launches began to be named under the cover 'USA.' Launches so identified are: 1984-59A (USA-1), 1984-65A (USA-2), 1984-65C (USA-3), 1984-91A (USA-4), 1984-97A (USA-5), 1984-127A (USA-6), 1984-129A (USA-7), 1985-10B (USA-8), 1985-14A (USA-9).

1984-65A, orbit was 170 x 263 km, 88.85 min, 96.43° manoeuvrable, it decayed after 113 days.

1984-65C orbit is 690 x 710 km, 89.79 min, 96.10°.

1984-112A, Cosmos 1607, the nuclear reactor was boosted to a 104 min, 950 km orbit on 1 Feb 1985.

1985-1A, Sakigake, was launched from the Tanegashima Space Centre, not Kagoshima.

1985-2A, Cosmos 1616 decayed or was recovered on 4 Mar 1985 after 54 days.

Rockets, Missiles and Spacecraft of the National Air and Space Museum

G.P. Kennedy, Eurospan Ltd., 3 Henrietta Street, London WC2E 8LU, 1983, 165pp, £8.50

The rockets, missiles and spacecraft in the National Air and Space Museum in Washington, USA, are an outstanding collection of artefacts from the US space programme. Through agreement with NASA, the NASM became the sole custodian of all major American space exploration artefacts, many of which, nowadays, are loaned to other museums throughout the world.

The collection is impressive. It includes, for example, all US manned spacecraft, except Gus Grissom's Mercury capsule which was lost at sea, 122 space suits, three Saturn V's and every major type of rocket engine from the V-2 onwards.

Besides flown spacecraft, NASM has preserved many design, development and test models. In cases where the spacecraft was not assigned to return to Earth, flight backups or test models have been saved for display instead. An example of this is probably the most impressive artefact in the entire collection - the black, white and gold backup Orbital Workshop of Skylab, which is also the largest object in the Museum.

This catalogue contains brief descriptive articles by staff members about each of the major space artefacts on display, exhibited in eight galleries and each having a distinct theme.

The catalogue, of course, describes only a small part of the NASM display. There are 23 exhibit areas in all ranging from the Wright Brothers original flyer of 1903 (now being renovated: visitors can observe through glass panels as the work progresses) to models, uniforms, instruments, medals and insignia which document most of the major achievements, both historical and technical, of air and space flight.

Not generally known is the Paul E. Garber facility, open as a 'no frills' museum and located in Suitland, Maryland. It is crammed with more than 100 aircraft and spacecraft, either in storage or in course of renovation, housed in five hangars. Few of the visitors to NASM go on to the Garber facility, and are undoubtedly the poorer for that.

The Cambridge Atlas of Astronomy

Eds. J. Audouze and G. Israël, CUP, The Edinburgh Building, Shaftesbury Rd, Cambridge CB2 2RU, 1985, 432pp, £29.95.

A wide range of astronomers has contributed to this 432 large format page impressive volume, which includes more than a thousand photographs and illustrations. It covers the whole broad sweep of astronomy, from the Earth itself, out past the Sun and planets and on to the most distant galaxies and quasars.

The 1980's is an exciting period for space exploration: the early manned space spectaculars have been replaced by the regular flights of the Space Shuttle to launch and service satellites, to carry scientists into orbit to do research on board Spacelab and, in 1986, to bear the Space Telescope aloft to provide the most detailed views yet of deep-space objects. The images returned by orbiting satellites have contributed enormously to our astronomical knowledge, revealing the discrete rings of Saturn, the birth of stars, the galactic centre and distant X-ray sources. The exciting programme continues throughout the 1980's with the close encounters of Giotto and Vegas 1 and 2 with Halley's comet and the Voyager 2 fly-by of Uranus in 1986. Results of all recent astronomical investigations are included with analysis and explanation from a team at the forefront of modern astronomy and astrophysics. The *Atlas* is completed by the inclusion of chapters on the history of astronomy and on cosmology.

Utilization of Outer Space and International Law

G.C.M. Reijnen, Elseiver Scientific Pub. Co., 52 Vanderbilt Ave., NY 10017, USA, 1981, 180pp, $63.75

One aim of the volume is to highlight some of the many intricate problems with which Space Law is confronted. The first chapter investigates the concept of the term 'sovereignty' since one of the basic principles of international law that has deeply influenced the shape of today's Space Law is the principle of State sovereignty. The second chapter discusses the problem that the body of Space Law refers both to sovereign States and to international organizations. The third deals with the Committee on Space Research - the first international space research organisation of non-governmental, purely scientifi character. The fourth chapter investigates to what extent Space Law offers safeguards against certain types of nuclear power sources in outer space.

Chapter 5 reviews the characteristics and legal implications of remote sensing by satellites. Chapters 6 and 7 then deal with direct broadcast satellites and investigate the present practice of private enterprise and the status of Space Law rules in relation to it.

Radiotelescopes

W.N. Christiansen and J.A. Hogbom, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, 1985, 263pp, £30.

The first edition of this book was widely acclaimed. A second has now been revised and expanded to take account of many changes which have occured since the first appeared 15 years ago. In particular, the chapter on aperture synthesis techniques has been completely rewritten.

The evolution of radiotelescopes from simple dipole arrays and parabolic reflectors to sophisticated image-forming instruments controlled by computers has meant that these new instruments are now the main tool of radioastronomy. The authors confine themselves to energy-collecting devices and do not deal with the associated electronics but include sufficient theory to enable the reader to understand the fundamentals of radiotelescope design.

This book will interest not only graduate students and research workers requiring a basic knowledge of radio astronomy but should also be of value to designers of highly directional radio-antenna systems in other fields.

Sky Catalogue 2000.0
Vol. 2: Double Stars, Variable Stars and Nonstellar Objects

A. Hirshfield and R.W. Sinnott (Eds), CUP, The Edinburgh Building, Shaftesbury Rd, Cambridge CB2 2RU, 1985, 385pp, £17.50 (s/c), £42.50 (h/c).

The final edition of the Skalnate Pleso Observatory's *Atlas Catalogue* by Antonin Becvar appeared in 1964. With its wide availability and handy sections on stars of various types, star clusters, nebulae and galaxies, Becvar's work remained important as a compendium of data for amateur and professional astronomers during the past two decades. However, the face of astronomy has changed remarkably since then. Black holes and neutron stars have moved from the pages of science fiction stories into the everyday parlance of researchers. The cosmic microwave background was detected accidentally in 1965, and pulsars only two years later. The number of catalogued quasi-stellar objects has increased from a handful in 1964 to thousands. Two decades ago optical astronomy reigned supreme, radio astronomy was still limited by poor resolution to broad surveys of the sky and its X-ray relative was still in infancy. The profound influence of computers and solid state electronics on observational astronomy would be felt only in the next decade.

Sky Catalogue 2000.0 was conceived in 1978 to meet the

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

growing needs of amateur astronomers and educators, as well as professional astronomers and other scientists, for a convenient source of modern data about astronomical objects. Volume 1 appeared in 1982 and contained information on 45,269 stars of visual magnitude 8.05 and brighter. Volume 2 then began to be prepared. The increased availability of astronomical data in computer-readable form has made it possible to expand it far beyond the scope of Becvar's earlier work. In addition to the categories of astronomical objects covered in his catalogue, new sections on suspected variables, dark nebulae, quasi-stellar objects and X-ray sources are included. For every object class, there are more entries and a wider variety of information than in the *Atlas Catalogue.* The galaxies section, for instance, contains data for nearly twice as many systems; Becvar's Radio Sources chapter was limited to only 38 well-observed objects but this volume has more than 700.

The catalogue consists of 15 main data sections, each devoted to a particular class of celestial object. The sections are arranged roughly in order of increasing scale and/or distance of the classes under study; hence progressing from double and variable stars to clusters and nebulae. The confines of the Milky Way are then breached with tabulations of galaxies and quasi-stellar objects. In order to demonstrate the wide variety of astronomical systems that can be 'seen' beyond the narrow optical band of the spectrum, concluding sections are devoted to radio and X-ray sources. Several additional tables appear in the Introduction, including complete lists of Messier objects and the Local Group of galaxies.

DO YOU REMEMBER?

25 Years Ago...
22 June 1960. US Navy navigation satellite Transit 2A, accompanied by Solrad 1, is launched by Thor-Able Star from the Eastern Test Range. Solrad was the first sub-satellite to reach orbit.

20 Years Ago...
2 July 1965. A Delta rocket places the US meteorological satellite Tiros 10 into orbit. The satellite relayed views of Earth's weather for 730 days.

15 Years Ago...
19 June 1970. Soyuz 9 cosmonauts Nikolayev and Sevastyanov return to Earth after a 17 day flight. The crew were noticeably affected by the mission, taking several days to readapt to Earth's gravity.

10 Years Ago...
15 July 1975. Soyuz 19 with cosmonauts Leonov and Kubasov and an Apollo spacecraft with astronauts Stafford, Brand and Slayton are launched on the first joint US-USSR mission. They dock on the 17th.

5 Years Ago...
16 June 1980. It is reported in the US that a 12-man Soviet space station will be launched in 1985 by a rocket of greater power than a Saturn 5.
23 July 1980. Vietnamese cosmonaut Col. Pham Tuan is launched aboard Soyuz 37. Col. Viktor Gorbatko commands the 8-day mission to Salyut 6.

K.T. WILSON

EDITORIAL

Continued from p.289.

cooperation in any high technology field, will be ready to exploit every difference as it appears and attempt to show that the enterprise is at best unrealistic and at worst the equivalent of selling one's technological heritage to those on the other side of the Atlantic. All those who have a real interest in promoting international cooperation on the Space Station will have to be very vigilant in the coming years to spot and combat the saboteurs. Unfortunately, it is often more attractive to be cynically destructive than it is to seek a working compromise in the face of a barrage of critics.

I can appreciate that, from a US standpoint, the growing European movement for an independent European Space Station is hardly the best visiting card to present at the commencement of the negotiations for participation in a joint programme. Of course, we in Europe must be thankful for the visionaries who are so far-sighted as to see even now that Europe needs its own Space Station. Even though it is financially highly questionable, I much prefer this attitude to the indifference to space that was much more prevalent in Europe until quite recently.

A senior German player on the space stage wisely summed up this potential conflict between cooperation and independence by saying that if the first space station is a success and there is a demonstration that it is going to be used to capacity, then it will be the most natural thing in the world for there to be more than one. We would hope that the two, three or more space stations would all have a high degree of compatability. The moral is that it is understandable for Europe to insist that present investments must be consistent with the later development of a European Space Station, but these considerations should not be allowed to spoil the chances of success for the present international Space Station that NASA is so bravely sponsoring.

But are we not neglecting the utilisation of the Space Station and, in particular, the cost of operating and using it? The argument is that one cannot start to make meaningful estimates of operating costs until the system has been defined etc, but this is perhaps not convincing. There are two threads: who is going to use it and how much will it cost? In spite of a few high profile potential commercial users of a Space Station, we are in real danger of building a system that will be under-used, and that more or less captive customers, such as the space scientists, are going to be rounded up as the main users. Attention is being given to this aspect, particularly within NASA, but we in Europe are lagging seriously behind. As to operating costs - a not unimportant factor in finding new users - where are the worthwhile estimates of the cost of operating or using the station of the 1990's? We are already late in starting preparations for utilisation - especially by newcomers to the space community who have quite strange notions on things like cost effectiveness, return on investment and similar wet-blanket slogans.

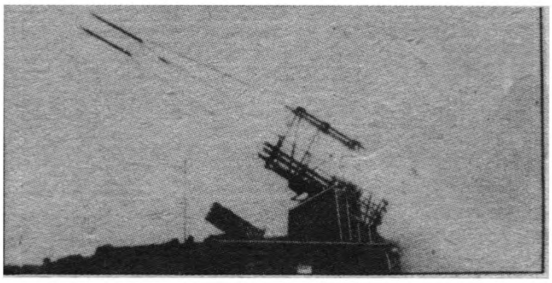
Industry has another responsibility: not to yield to the temptation to use the Space Station to have government pay for the development of their newest pet ideas, whether or not they are really the most appropriate. We need to exercise great discipline in using our scarce development money where it is really needed: to make the new system as attractive as possible to the new generation of users, rather than providing job satisfaction for the designers and builders of the system.

It is time for us to spend more time looking at the needs of those whom we need to persuade to form the next generation of space users.

ROY GIBSON
Space Consultant,
former Director General of the
European Space Agency

BIS HISTORY SYMPOSIUM

The second BIS History Symposium, on the theme of 'British Liquid Propellant Rockets,' will take place at Society Headquarters on **2 October 1985** from 10.00 a.m. to 5.00 p.m. Space Histories tend to concentrate on US, Soviet and German contributions to early rocketry but there is also a rich history of British participation in the field. The one-day symposium will cover liquid propellant motors from the Second World War to the end of the Black Arrow era (*c.* 1970).



The provisional programme includes:

1. 'Lox/Kerosene motors,' by I. Smith
2. 'Bristol Siddeley engines,' by D. Andrews
3. 'De Havilland RATO's,' by W. Neat
4. 'Other RATO's,' by J. Griffiths
5. 'Liquid hydrogen motors,' by A. Bond/A. Jeffs
6. 'Storable propellant motors,' by D. Lewis

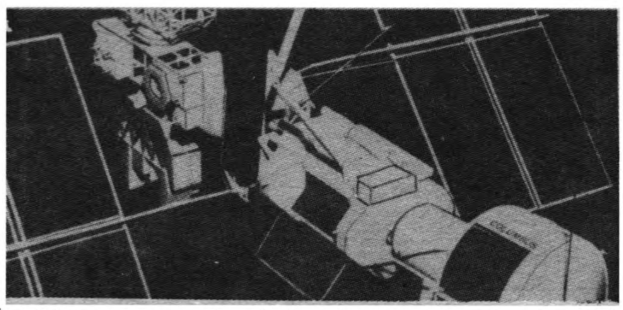
Registration forms are available from the Executive Secretary.

SPACE STATION APPLICATIONS

The second part of the successful Symposium on 'Space Station Plans' will follow at HQ, on 25 September 1985. The theme of Space Station Applications **will consider such topics as Earth observations, astronomical research, materials science and engineering, medical research, communications and the use of the Station as a staging and servicing post for payloads bound for higher orbits.**

The Society has long advocated permanently manned space stations so this Symposium is an important event in the space calendar. A panel of international speakers will present a series of papers to update present thinking on one of today's major space topics.

Offers of papers are invited. Potential authors are requested to contact the Executive Secretary, at 27/29 South Lambeth Road, London SW8 1SZ.



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Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01-735 3160.

NOTICES OF MEETINGS

ADDITIONAL MEETINGS ARE LISTED ON THE INSIDE BACK COVER

Lecture

Theme: **METEORITES: SURVIVORS OF THE EARLY SOLAR SYSTEM**
By Dr. A.L. Graham
Dept. of Mineralogy, British Museum

Meteorites are the most important source of information relating to the early history of the solid matter in the Solar System. They are the only material available for study dating back to the time of formation of the planets around 4500 million years ago. This talk will illustrate the variety of meteorites and the significance of the data obtained from them.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **18 September 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

40th Annual General Meeting

The 40th Annual General Meeting of the Society will be held in the The Grosvenor Hotel, Gallery Lounge, Buckingham Palace Road, London SW1 on Saturday **28 September 1985,** at 3.00 p.m.

Details of the Agenda will appear in *Spaceflight* in due course.

Council nomination forms can be obtained from the Executive Secretary. These must be completed and returned not later than **5 July 1985.**

If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members.

Symposium

A 2-day Symposium on the theme of **Towards Columbus and the Space Station** will be held in Bonn/Bad Godesburg, Stadthalle, W. Germany on **3-4 October 1985,** organised by the DGLR and co-sponsored by the BIS, AAS, AIAA, AAAF and AIDAA.

Further information and registration forms will be available from the Executive Secretary in due course. Please advise BIS headquarters as soon as possible if you plan to attend.

36th IAF Congress

The 36th Congress of the International Astronautical Federation will be held in Stockholm, Sweden on **7-12 October 1985.** The theme is:

PEACEFUL SPACE AND GLOBAL PROBLEMS OF MANKIND

Members of the Society wishing to present papers are asked to notify Dr. L.R. Shepherd, Chairman of the BIS International Liaison Committee at Society HQ as soon as possible. Members wishing to present papers to the IAF Student Conference must submit them through the Society.

Lecture

Theme: **THE OORT COMETARY CLOUD: PROBLEMS AND PERSPECTIVES**
By Dr. M.E. Bailey
University of Manchester

The physical structures of comets, observations bearing on their sites of formation and the usual steady-state 'Oort Cloud' theory of cometary origins will be reviewed. Several apparently severe problems for this general picture will then be described, emphasising that the 'Solar System vs Interstellar' debate continues and the validity of the steady-state Solar System model remains unresolved.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on **30 October 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture

Theme: **OUR PRESENT KNOWLEDGE OF THE ASTEROIDS**
By Prof. A.J. Meadows
University of Leicester

In the last few years, knowledge of the asteroids, and more especially of their physical properties, has increased greatly. A major reason is the rapid growth of new instrumentation, both ground-based and on satellites, which can be applied to their observation.

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **20 November 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:

3 Jul 1985
7 Aug 1985
18 Sep 1985
30 Oct 1985
20 Nov 1985

Membership cards *must* be carried and be available for inspection before admittance.

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

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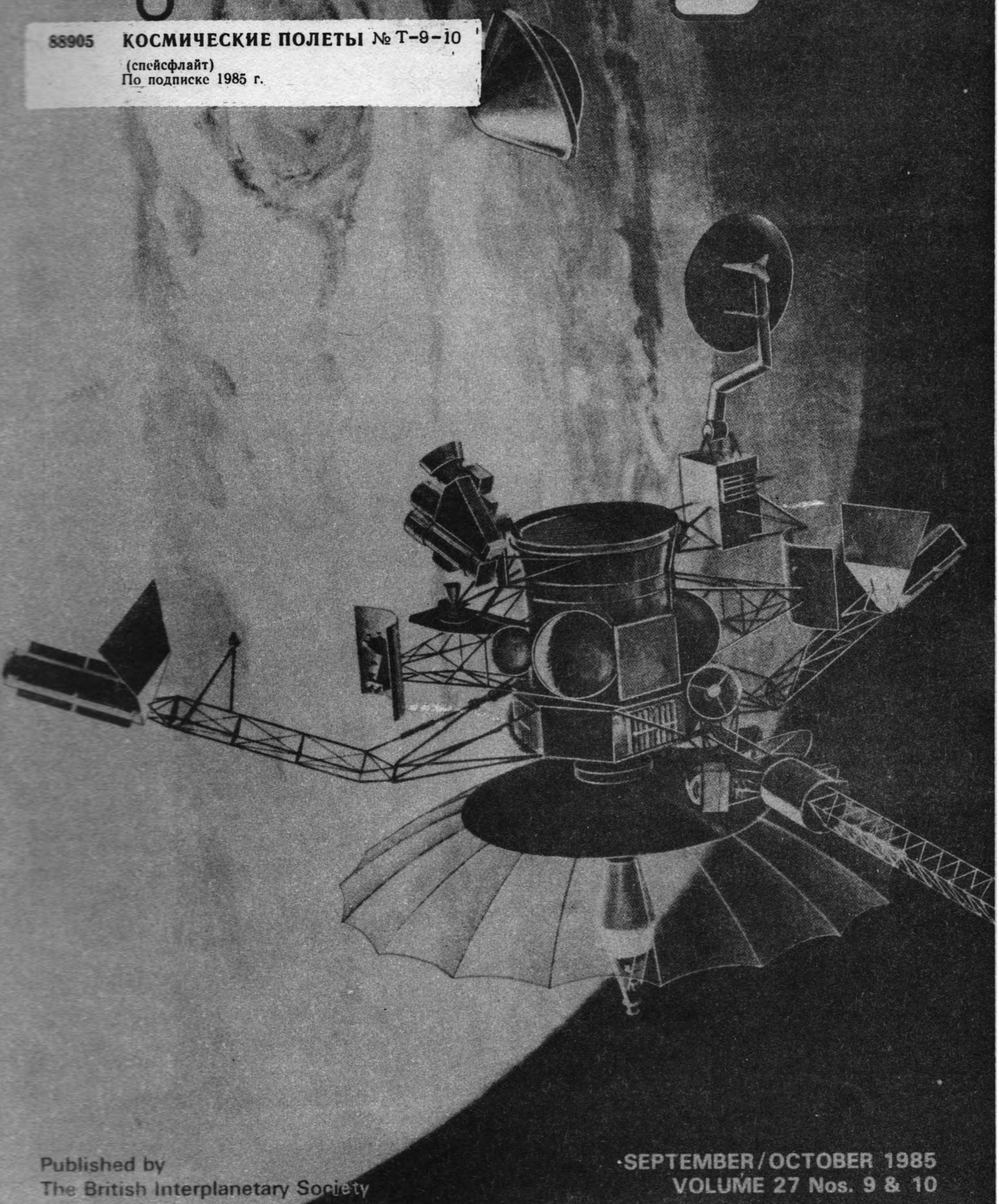

Published by
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SEPTEMBER/OCTOBER 1985
VOLUME 27 Nos. 9 & 10

A PIECE OF ASTRONOMICAL HISTORY

As interesting articles in Spaceflight **(March and June 1985) have related, the Society is fortunate to possess a unique copy of an early important astronomical star atlas and, in view of its importance, plans to issue facsimile copies in limited edition.**

The Uranometria **(Atlas of the Heavens) first appeared in the year 1603. Its author was a Bavarian lawyer, Johannes Bayer (1572-1605). It was such a boon to astronomers that it continued as a major work of reference throughout the 17th and 18th centuries.**

Basically, it consisted of a finely-engraved frontispiece with 51 copper-engraved star maps recording the approximate positions and magnitudes of some 500 stars observed by Bayer himself, in addition to those that had formed the renowned catalogue of the Danish astronomer, Tycho Brahe, only a year or two earlier.

The Society's copy is even more important than this. The Bayer star maps are interspersed with sheets of carefully-catalogued handwritten observations identifying the exact position of each star shown for Epoch 1747. It is apparent that this is the work of a dedicated astronomer of high calibre. Research is still continuing to identify who this mysterious observer might be but early candidates have included James Bradley (Third Astronomer Royal) and George Parker (Earl of Macclesfield), among a host of outstanding historical figures.

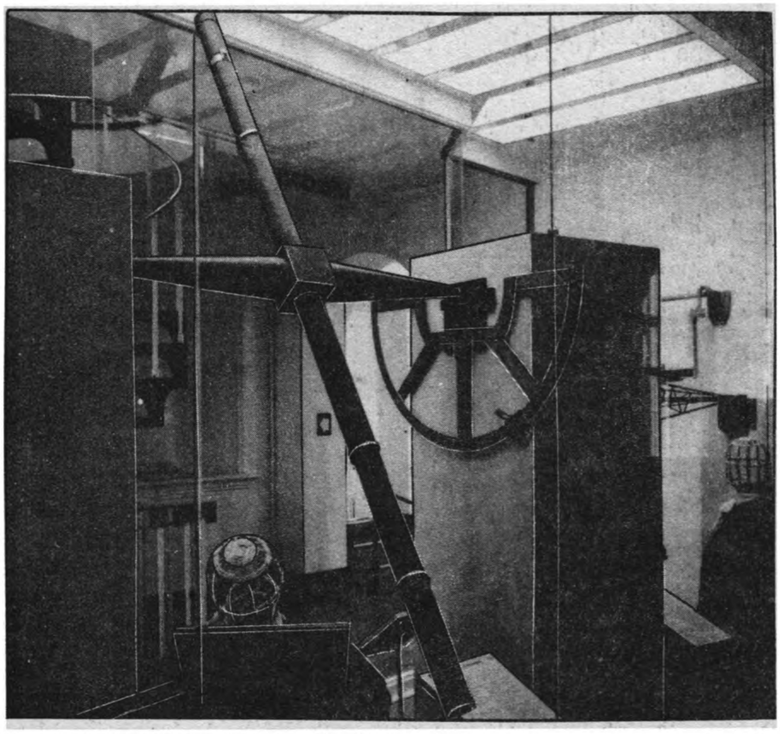
The Bayer large-scale maps and accompanying writings will be reproduced, using the photographic plates carefully prepared in the initial stages of the investigations.

Johannes Bayer, the author of *Uranometria*. The drawing is taken from a rare portrait in Munich showing Bayer as he appeared in the late 16th century.

Only 500 copies will be made. Two versions will be available, one bound in Buckram (£160) and the other in calf vellum (£250). They will be identical in all respects except for the binding. Members interested in securing copies at a special pre-publication price should apply to the Executive Secretary at HQ.

Currently only a few good copies of the first edition of Uranometria **are on the market. Their cost averages about £4,500 each though one auctioned in 1980 reached £6,500. These consist solely of the star maps with Latin wording on the reverse of each. Later editions are slightly cheaper, with one in good condition costing about £2,500.**

These prices, of course, disregard the fact that our own facsimile, although with a slightly damaged frontispiece, has been more than doubled in size by the inclusion of page after page of additional observations. The enormous labour that went into making these observations underlines the outstanding character of the book.



Above: Nathaniel Bliss, Fourth Astronomer Royal, is another candidate as the original owner of the Society's unique Bayer Atlas.

Left: James Bradley, Third Astronomer Royal, could also have made the additional observations extant in the Society's Bayer. This is Bradley's transit instrument, now preserved at Greenwich. *RGO*

spaceflight

A Publication of The British Interplanetary Society

Founded 1933 *Incorporated 1945*

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Editor
G. V. Groves

Managing Editor
A. Wilson

Assistant Editor
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CONTENTS

NEXT GENERATION SPACE TRANSPORTATION

The growth of any transportation system is a complex interaction between the capabilities of the carrier on the one hand and the requirements of the customer on the other. From the introduction of the V-2 as a military weapon to its subsequent use as a multinational civil space research tool, there has been a continuous feedback cycle to meet the space transportation needs of science and commerce and the military and political demands of governments. The response has been an evolutionary array of launchers which has led to larger payloads, better performance and greater economics.

There are currently six economic communities with launcher capabilities, the USA, USSR, Europe, Japan, China and India. Heavy low orbit payloads (20-30 tonnes) lie within the capacities only of the USA and USSR. Europe can currently place about six tonnes into low orbit and about 1.5 tonnes into geostationary orbit. Chinese and Japanese capabilities are similar, i.e. about 800-900 kg in geostationary, while India's current vehicles can orbit only small (a few tens of kg) scientific payloads. Those who have witnessed the development of the current state of space transportation find these values impressive. Even so, pressure from vehicle users is still intense and becoming even more so, particularly from commercial and military quarters. There is even evidence that the prestige space programme is still important.

The demands for cheaper and more reliable launch vehicles for commercial work in the 1990's have caused both Japanese and Europeans to embark on the design of a new launcher generation, the H2 and Ariane 5 repectively. Several European studies on spacecraft having high performance transfer stages from low Earth orbit to geostationary orbit indicate that an economic payload mass will be about seven tonnes. The Japanese H2 vehicle will have a launch mass of about 240 tonnes and a payload capability of about six tonnes: the 500 tonne Ariane 5 will have a capacity of about 15 tonnes, corresponding to two or three geostationary payloads. The configuration of both new generation launchers are similar and reflect also the much heavier (2000 tonne) USA STS system, comprising a Lox/Liquid hydrogen core parallel staged with solid propellant motor boosters. The fact that two independent nations should, after much optimisation study, confirm the value of the expendable design features of the US space transportation system is good evidence that this layout is the most economic currently available. Both the Japanese and European launchers will probably carry Lox/LH_2 orbit transfer stages, as will the Space Shuttle, but there are major differences in all three nations' engine technology. The Japanese and USA hardware will

Continued overpage

COVER

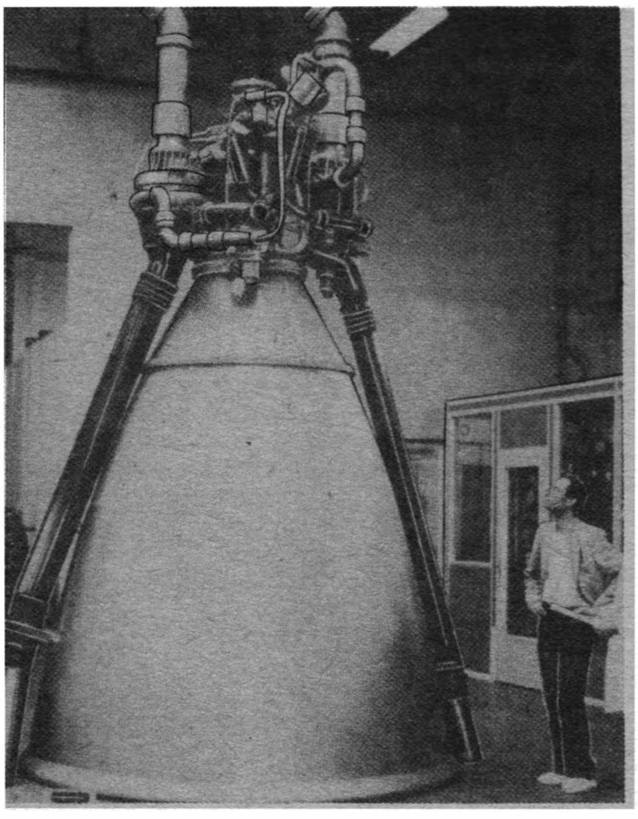
NASA is preparing for the first two launches of the new Shuttle/Centaur-G combination next May. The first, carrying ESA's Ulysses solar polar probe, is scheduled for a 15 May liftoff on Mission 61F with *Challenger*. Just six days later, *Atlantis* is due to go aloft carrying the Galileo Jupiter orbiter and probe (pictured on the cover). *NASA*

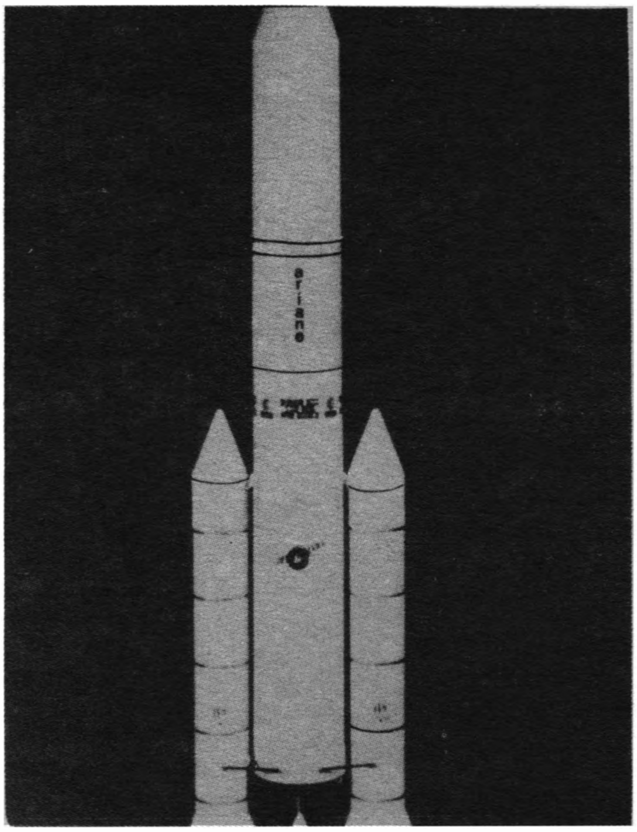
employ preburner closed cycle engines in lower stages and advanced expander closed cycle engines in upper (transfer) stages. The European stages, however, will employ lower performance gas generator open cycle engines throughout. Both of the new vehicles are now, essentially, committeed programmes. The Japanese are somewhat ahead of the European programme though both are due to fly in the first half of the 1990's.

As an intermediate step, and in order to keep pace with the market, Europe will introduce the 470 tonne staged Ariane 4 in 1986. This has liquid propellant boosters based on the Ariane 2/3 technology strapped to the Ariane first stage, which has been lengthened to accommodate over 50% more propellants. It will, with the aid of an apogee motor, be able to place satellites of up to 2.5 tonnes in geostationary orbit. This and the other Ariane variants will, however, be phased out when Ariane 5 enters service. There are no clear indications that China or India will develop large vehicles for geostationary missions though China has recently moved into the commercial field with the 200 tonne Long March 3 vehicle. This launcher can place 1.4 tonnes into geostationary transfer orbit. It appears to be a vehicle derived from a conventional weapons system based on storable propellants. It may well capture a significant portion of the medium mass spacecraft when other launchers have been optimised to higher payloads, in much the way that Ariane 2/3 followed the STS very successfully.

Although far from a new vehicle, the USSR has also recently offered the Proton vehicle as a commercial launcher. Information is scarce as to its design and performance outside the USSR, though it has seven near-identical clustered modules for lower stages (only six of which ignite on the ground) and an upper stage. For higher orbits and interplanetary missions a further stage is added. The vehicle employs storable propellants throughout. It probably has a mass of about 780 tonnes and can place about 20 tonnes in low orbit and over two tonnes in geostationary. It has been suggested that the Russians have many Protons available, waiting for launch.

The HM60 engine will be used on the Ariane 5. *ESA*





A concept for the Ariane 5 launcher. *ESA*

It seems from all this that commercial transport systems are determined up to the year 2000. However, there is much discontent from users because launch costs are both too high and unreliable. There is an additional factor because the USA will add a manned research presence in space with the emergence of Space Station in the early 1990's. Since that is the only country, outside Russia, with man-rated vehicles, this gap has led the French to propose Hermes, a small shuttle to be flown by Ariane 5 and adopted by ESA. Indeed, it is this very idea that has caused Ariane 5 to be designed beyond commercially optimum payloads. Hermes itself would have only about a 4.0 tonne payload for a low inclination launch and half that in polar orbit. Its total mass would be about 18 tonnes and it could carry two to six crew members. If adopted, Hermes would fly in about 1997. While this might satisfy European manned presence requirements, its economics have been questioned and it has been suggested that Hermes probably has undisclosed military applications in addition to civilian use. In a more imaginative attack on launcher economics, the UK has advised ESA of a national investigation into a fully reusable vehicle of a type uninspiringly called HOTOL (Horizontal Take Off and Landing).

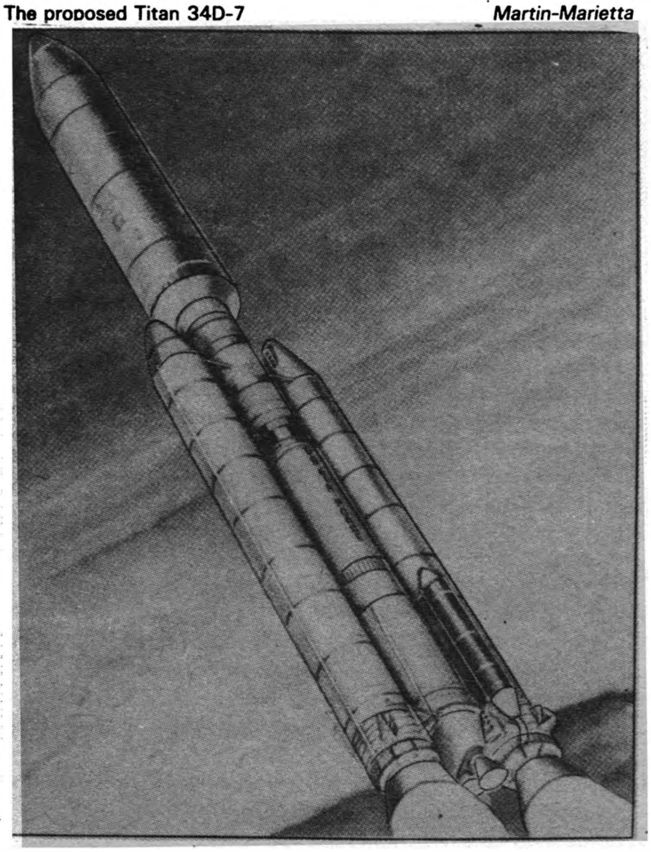
This 200 tonne vehicle would make use of advanced structures, aerodynamics and airbreathing as well as rocket propulsion technology to realise a single stage to orbit (SSTO) and return capability with no expendable hardware. It would have a payload of about seven tonnes and whilst nominally unmanned could conceivably carry a manned module in place of, or as part of, the payload. Although still only a study at present, HOTOL seems to show a technological capability which will almost certainly be introduced by year 2000.

The USA has had ongoing investigations for several years now on the 'Mark II' fully reusable shuttle for a year 2000 replacement of the current STS, and with the

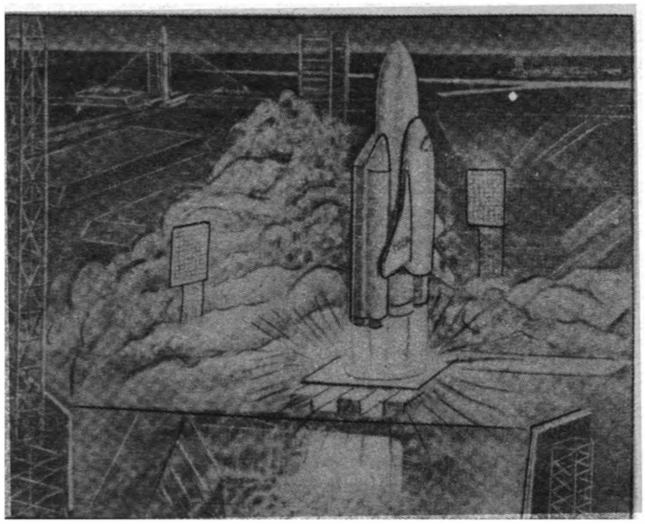
military requirement in mind for a manned 'instant readiness' space interceptor with SSTO characteristics, called the trans-atmospheric vehicle (TAV). The TAV study phase has been in progress for several years, involving all the major USA aerospace firms. About half a dozen design concepts appear to have survived the first round of investigation. These propose various propulsion means, ranging from advanced dual fuel rocket engines to advanced airbreathing systems. Both the UK and US projects are almost certainly our first glimpses into the gestation of 21st century space transportation systems.

Apart from these vehicles, it seems that the USA has a need for both expendable medium lift launchers and a heavy lift launcher. The USAF requirement for medium lift capability will be provided by the 800 tonne Titan 34D-7 able to fly about 20 tonnes to low orbit or 4.5 tonnes to geostationary. This is not a new vehicle but one developed from the existing 34D by use of a Shuttle compatible Centaur stage and seven segment solid boosters. The heavy launch vehicle will probably be Shuttle hardware derived and, with a launch mass of about 2000 tonnes, be capable of placing about 140 tonnes in low orbit. It is required for the early 1990's in support of the USA intention to re-establish a lunar and beyond mission capability. It is also needed to support the USA military programme. Little has been said about the USSR launcher developments because we have insufficient information. However, the American policy of making available 'watered down' versions of their intelligence material on Russian activities in the annual publication *Soviet Military Power,* allows some insight to be gained. Additionally, a Soviet paper addressed to the Lausanne IAF meeting in 1984 discussed economic optimisation of launchers and spacecraft. From these meagre sources, plus the writings of Russian rocket engineers and the little that is known of the ill-fated TT-5 launch vehicle of the old USSR lunar programme, we may speculate as follows:

1. The Russians are building a transportation system having a medium capability of 15 tonnes to low orbit and a heavy capability of over 200 tonnes to low orbit.
2. They also have a large shuttle of mass about 155 tonnes with a payload capability of 90 tonnes and may have a smaller manned vehicle or spaceplane, to be launched by the medium lift launchers.
3. Central to the heavy lift vehicle and heavy shuttle is an altitude-ignited Lox/Liquid hydrogen core with strap-on liquid boosters. These latter items possibly use Lox/UDMH burned in preburner cycle engines derived from the first and second stage of the TT-5 programme. The lift-off mass of the heavy vehicle with six strap-ons would be near 4000 tonnes. With a four strap-on version carrying the heavy shuttle the lift-off mass would be about 3000 tonnes.



The proposed Titan 34D-7 *Martin-Marietta*



A concept of the Soviet large shuttle (from *Soviet Military Power*).

The medium lift vehicle may use one of the strap-on boosters as its first stage. A Lox/UDMH second stage with propulsion derived from the third stage engines of the TT-5 would result in a total vehicle of about 520 tonnes launch mass.

It has to be re-emphasised that the above is based on limited but probably sound evidence. If correct, this could explain the drive in the USA to TAVs and their heavy lift launcher programme.

There is not only a well-known and declared Russian interest in large space stations, Lunar, Martian and even Jovian manned missions over the next 20 years but little doubt that, like the Americans, the Soviets have considerable military motivation behind their extensive new launcher family.

The next 15 years, therefore, will probably see the appearance of powerful new launch vehicles. Many will be unmanned, transfering payloads to geostationary and polar orbits and optimised for reliability and economy. Others will be manned, including crew and supply missions to space stations. Advanced unmanned missions from the USA, USSR and Europe will probe the deeper parts of the Solar System, thus demanding considerable lift capability to parking or escape orbit. This could also lead to a revival of prestige missions to the Moon and planets. The launch vehicles likely to be involved in that contest and now under development are no longer the few built of the Saturn 5/TT-5 class, but systems likely to endure for several decades. Finally we stand to see the emergence of the first genuine space ships in the Mark II Shuttle, TAVs and, perhaps most promising of all, HOTOL.

The Aerospace Transporter Concept

Sir, The announcement of the British Aerospace project for a single-stage-to-orbit horizontal take-off vehicle, Hotol, rightly claimed as a major advance in transportation into low orbit, must bring back memories to many engineers. Some will recall studies undertaken 20 years ago in their respective companies of non-ballistic launch vehicles. Some also participated in the group formed by Eurospace, the European Association of Aerospace Companies, in the early 1960's.

In 1963 this group held its first meeting at Eurospace headquarters in Paris. Numbered among its members were specialists in power systems and advanced aerodynamic concepts drawn from several European countries, in particular France, Germany and the UK. Its most distinguished member was Professor Sanger, one of the pioneers of the reusable spaceplane concept. The UK representation was significant and included companies such as Bristol Siddeley Engines, Hawker Siddeley Aviation, Bristol Aircraft Corporation and Rolls Royce.

Most of the companies in the group at that time were studying multi-staged projects using ramjets, turbojets or turborockets, advanced aerodynamic systems and assisted take-off procedures, but were faced with difficulties in obtaining adequate support, particularly financial, from their governments for these basically ambitious projects. Thus it seemed that the combined expertise they possessed could be directed towards a joint European venture.

As early as 1963, Eurospace was campaigning for a long-term European space programme and appreciated that the space stations of the future would require adequate logistic support, using vehicles that preferably should be capable of being launched from, and return to, a predetermined site.

The group initially examined mission requirements and postulated some basic design aspects, notably the need for recoverable stages, using rocket or air-breathing systems or combinations of both, possible assisted take-off devices, the attainment of a 200 mile orbit, acceleration limited to 2.5 g, a 2.5 tons payload and a two-man crew. At that time it was recognised that the ideal single-stage-to-orbit vehicle was beyond the scope of contemporary technology, but nevertheless was a target for future development.

Thus, a number of possible configurations were considered, the time schedule estimated (10-15 years) and the size and form of the research programme examined. It was calculated that the average annual expenditure required would be of the order of £40 million per annum (1964 values) over the period under consideration.

However, the Group's modest request at that time was for the European governments to provide a £2.5 million for a feasibility study. In the event of a positive outcome to this study it was recommended that a consortium of the companies in the group be formed to manage the project, possibility under ELDO's direction. The findings of the group were published by Eurospace in 1964 in a report entited *Aerospace Transporter*.

This proposal aroused considerable interest and featured as a major theme at several conferences at that time, including a BIS Symposium in November 1963 on Aerospace Vehicles. However, the most interesting reaction to the proposal occurred at the second Eurospace US/European Conference in Philadelphia in April 1965 when it was presented to the US space industry and NASA. The US industry's reaction to this proposal can almost be called derisive; it was suggested that such a project was too advanced, well beyond the capability of European industry and that the Europeans should confine themselves to more modest targets, preferably by participating in US projects.

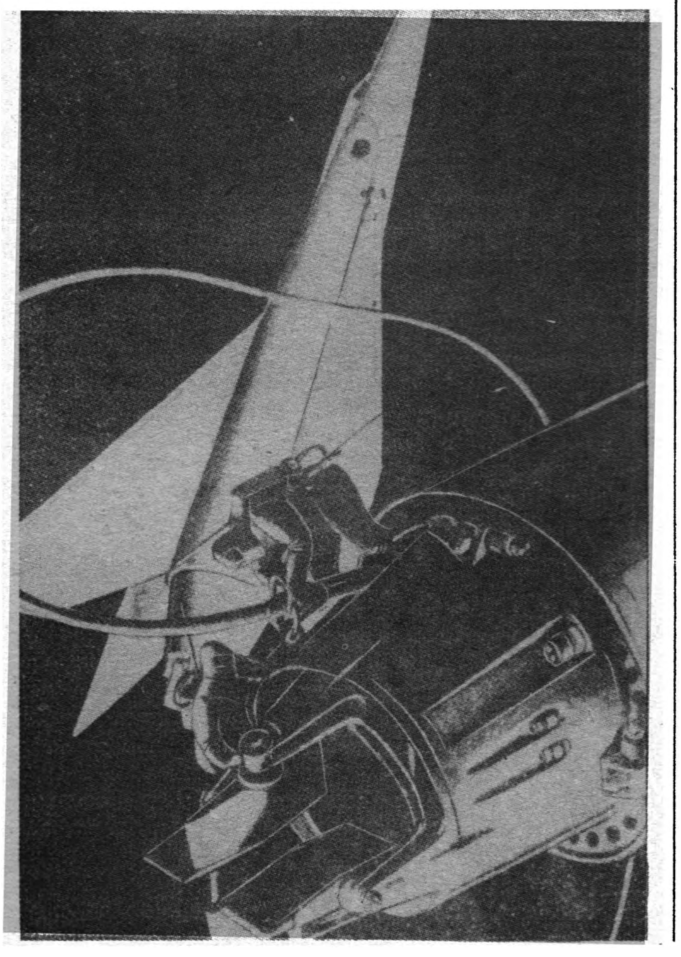
Since the European governments' attitudes were also unimaginative and shortsighted, the Aerospace Transporter concept was gradually shelved and then forgotten; especially after ELDO was disbanded in 1973. In the UK, expertise in this field gradually evaporated and the need for any European launcher capability was considered unnecessary: would not the USA provide all Europe's launcher requirements?

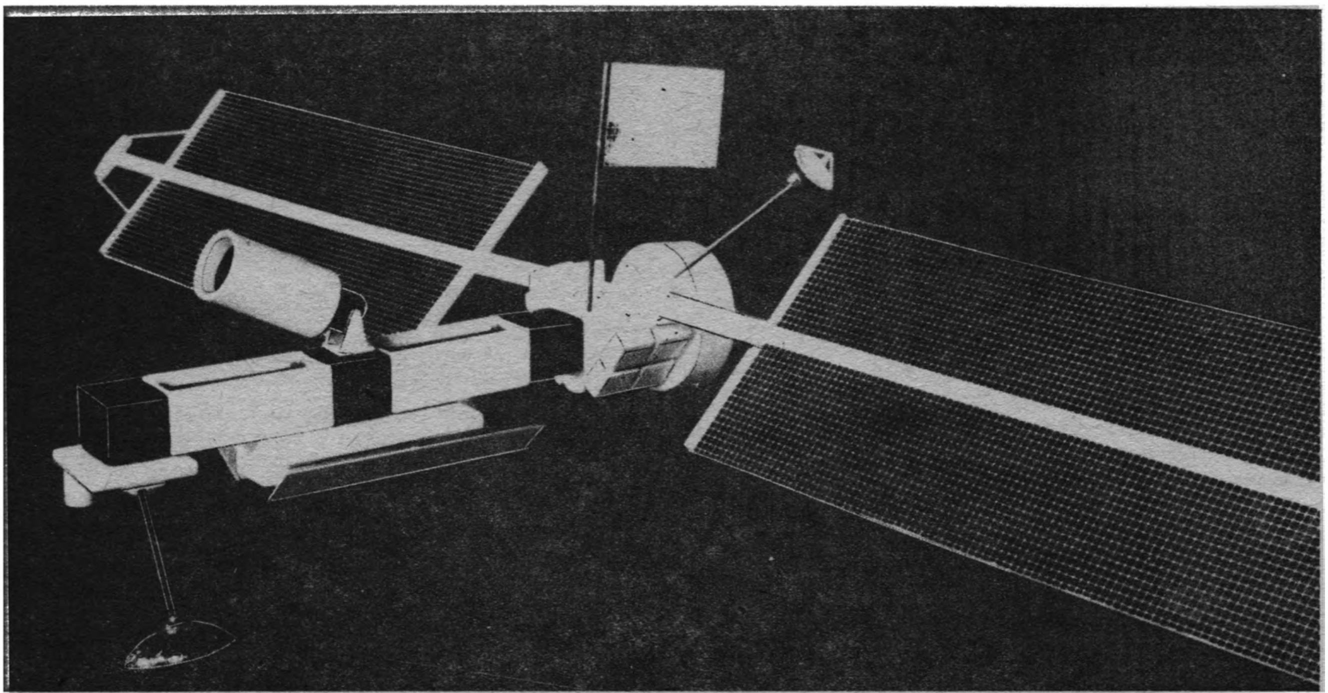
Fortunately for the future of European space activity, this view was not shared by other European countries and, as a result, Europe has achieved a respectable degree of independence in space activity which it is hoped will expand as a result of the ESA conference at Ministerial level in Rome during January.

However, would not Europe, and the UK in particular, be in an even more advantageous position if the governments had exercised just a little more imagination 20 years ago? Perhaps Hotol would already be flying.

REX TURNER
Technical Secretary
Eurospace

Like many other space techniques, the Society was interested in shuttle-type vehicles long before the concept became a reality. This 1954 R.A. Smith painting shows a shuttle craft being used for orbital refuelling - an idea tested in orbit by the US Shuttle last October.





The British Aerospace proposal for the Space Platform component of the NASA Space Station (see the item of correspondence below) underwent design changes earlier this summer. This is a model of the new version showing, for example, the solid central body in place of the previous open design. *BAe*

Further Thoughts on the Space Station

Sir, A few additional matters can be added to the letter from Mr. Goody (*Spaceflight* July/August 1985 p.290). The Task Force created in May 1982 to examine the scientific uses of space stations had the following objectives:

a. To develop scientific uses created by the Space Station itself.

b. Determine any effects the development of a Space Station might have on existing scientific space programmes.

c. Identify focal points in developments affecting the Space Station.

At first, a somewhat ambiguous feeling was revealed in the minds of some scientists towards the development of a Space Station, both on technical grounds and on uncertainties about how this would affect their funding. The result was that the most constructive advice emerged from within NASA itself and its contractors. During these deliberations, particular concern emerged over the following matters:

1. The need to eliminate costly delays; in the past these had fallen particularly on scientific missions.
2. A requirement for an advanced communication information system designed, particularly, to meet the needs of scientific users.
3. There was apparent lack of interest in a large multi-use co-orbiting platform. Free-flyers were preferred, particularly if several could be mated together.
4. Great emphasis was placed on teleoperations, based on automation, robotics, computer vision, expert systems and human interfaces.

To these, of course, could be added the development of a class of interplanetary vehicles more suited to the space environment to aid further exploration. In regard to (1), the view of US scientists had been tempered by difficulties encountered during the development of the Shuttle, though they equally complained of a substantial decline in NASA funding for space science. In reply, it was pointed out that the Space Station made possible the use of scientific apparatus previously excluded by reason of mass, volume and power. It opened up substantial new opportunities e.g. with large materials processing furnaces and tether facilities several hundred km away.

Approx three-quarters of the potential users favoured a 28.5° orbit, the remainder preferred a platform in a near-polar 90° orbit. The latter would never meet the Space Station, though both would possess a common transport infrastructure and share a common basic design unit. The polar platform, in a 400-800 km orbit, would contain a propulsion module which would enable it to be brought down to a lower orbit, say every two years, for servicing *via* a Shuttle launched into a polar orbit from Vandenberg.

The basics which thus emerged for:

a. A large module providing a shirt-sleeve environment to assemble, test and check-out instruments. This would also enable the maintainance and repair of coorbiting facilities to be carried out (e.g. by refills of expendables and possible replacement of equipment) by an orbital manoeuvring vehicle.

b. The capacity to assemble large instruments, with examples such as large refractors, an infrared submillimetre telescope and other systems of modular imaging collection.

c. All should be packaged readily on the ground for assembly in orbit, thus giving a much better launch capacity as well as obviating risks such as those that attended Skylab.

d. Solar physics and cosmic ray research, particularly, would benefit considerably from a manned presence.

P.R. FRESHWATER
Henley-on-Thames, Oxon

Tubeless Telescopes

Sir, The Maypole telescope used by Pound and Bradley, referred to in our President's letter (*Spaceflight*, April 1985, p.149) was, really a tubeless telescope. It consisted simply of a long pole with an object glass mounted at one end and the viewing glass at the other. *Early Science in Oxford,* (Vol 2) by R.T. Gunther (Oxford Historical Society printed by the Clarendon Press 1923) provides a detailed account of how such a telescope worked. It also mentions a plan to set up a replica, using an original from the Royal Society but this was abandoned as being too difficult.

With the Maypole telescope, the object glass was mounted in a short tin tube, rigidly fixed to the side of the 12 ft long pole, rather like a rocket fixed to its stick, the whole thing then being attached to a convenient tree or pole by a ball and socket joint. This allowed free movement to the height needed for making the desired observation. A silk cord attached to the tail end of the stick enabled the object-glass, by a gentle pull, to be moved to the proper alignment.

The eyepiece was also fixed on a short stick, in such a way that it could be moved up and down until distinct vision was obtained.

This cumbersome arrangement undoubtedly met with success in Pound's hand, for his observations of the five known satellites of Saturn enabled Halley to 'rectify' their movements, though the disadvantages of this 'aerial instrument' was severely criticised subsequently by J. Crosthwait.

The 120 ft-odd long pole introduced other difficulties, one being how to *find* the object glass in the first place.

Even so, the arrangement was a great vogue at the time. Halley, for example, had been ordered earlier 'to view the scaffolding at St. Pauls to see if that might not conveniently serve, for the present, to erect the object glass thereon for viewing such of the celestial objects as now present themselves.' Christopher Wren too, so it is said, envisaged that the 202 ft high Monument in Mincing Lane, (where the Great Fire of London began) could serve as a tube for a long telescope.

M.W. WHOLEY
Midhurst, Sussex

Solar Constant and Climate

Sir, In his article on Solar Max and Climate (*Spaceflight* **27**, pp. 250-253, June 1985), Richard Lewis briefly discussed the importance of monitoring the solar flux and the contribution that the Solar Max mission is making to this problem. He mentions other space measurements of the solar constant that will be made during the remainder of this decade and concludes the article by stating that '... the study of climate has at least turned to the Sun.'

While the importance of these measurements cannot be denied, they are, however, of limited value for understanding climate when conducted in isolation of other measurements of the atmosphere. In recognition of this matter, NASA have developed the Earth Radiation Budget Experiment (ERBE), where the solar constant measurements are made in conjunction with accurate observations of the components of the radiation budget. From these ERBE measurements and regional measurement programmes over selected land and ocean areas and the International Satellite Cloud Climatology Programme (ISCCP) experiments, it will be possible to obtain a more complete understanding of the factors that influence the climate of the Earth.

ERBE measurements are now just beginning to arrive from instrument packages launched at the end of 1984 and which will be extended with a further set of instruments launched on NOAA-G in 1985. This integrated set of measurements, together with the independent solar constant measurements from other space platforms, will provide the observations to improve our understanding of possible links between any solar variability and the Earth's climate.

DR. GARRY E. HUNT
NASA ERBE Team

Archaeology from Orbit

Sir, In the February issue of *Spaceflight* there was a letter concerning possible archaeological uses of space images. We have recently been involved in one interesting use in the Yucatan Peninsula.

We used computer-enhanced Landsat images, taken from an altitude of about 900 km, to detect areas of vegetation change that might correspond to old Mayan agriculture and cities. The initial examination of the images suggested 112 'target areas' in a 10,000 square mile region of the Yucatan. We reduced that to a candidate list of 20, which were then examined by helicopter overflight - the dense vegetation did not permit a landing. Half a dozen of the sites correspond to Mayan developments. One of them, believed to be Oxpemul, is a site (near the village of Dos Aguadas) that had been 'lost' since the early 1930's. Another, near the village of Conhuas, was previously unknown to archaeologists and its Mayan name is still not known.

As another interesting point of space age techniques, the helicopter located its position by using the Global Positioning System, which uses exact triangulation from a system of navigation satellites to get latitude and longitude within a few metres. Once a site was reached, the techniques became a little more primitive. One man was lowered by rope from the helicopter to the top of the pyramid, in an attempt to clear enough of the vegetation to allow the helicopter to land. His saw broke and the effort was abandoned.

The final stage of this type of archaeological exploration is still dangerous and arduous. However, the early exploration, which can be done with computer, light table and space images in our offices, certainly beats hacking through the jungle.

CHARLES SHEFFIELD
Vice President,
Earth Satellite Corp.,
Maryland, USA

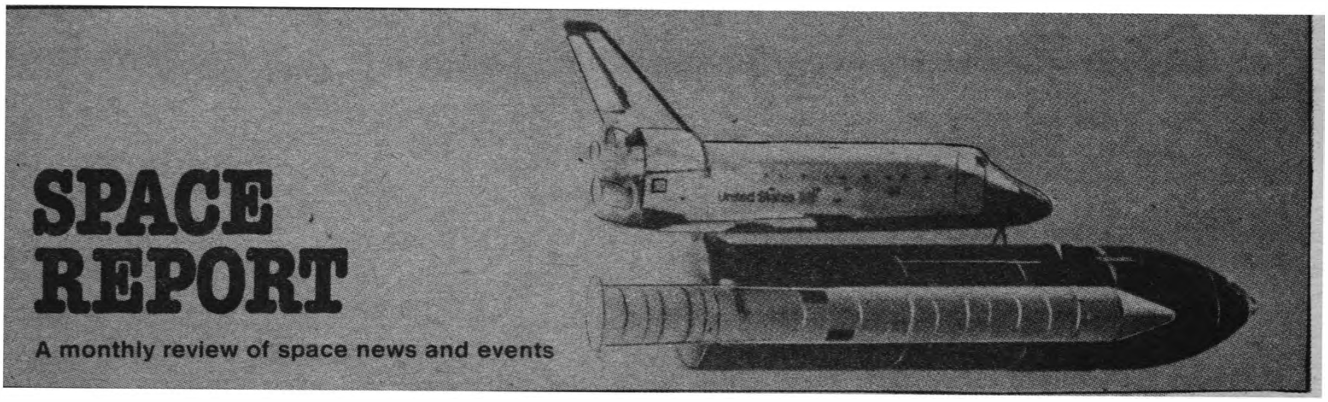
Salyut Corrections

Sir, I would like to correct some information in my last two Salyut Mission Reports. In the March 1985 issue of *Spaceflight*, p.134, the event times of the undocking day should be advanced by one hour. Soyuz T-11 landed at 1057 (not 0957) GMT, giving a mission duration of 236 days 22 hours 50 minutes. Moscow Summer Time ended on 1 October and the extra hour should not have been deducted.

Aleksei Leonov in the July/August 1985 *Spaceflight*, p.327 (final paragraph) actually said 'the creation of lasting orbital stations... is inconceivable without extra-vehicular activity of crews.'

NEVILLE KIDGER
Morley, Leeds

The Editor is always interested in receiving items of correspondence, notes, comments, or similar material for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine. The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.



SPACE STATION AGREEMENT

NASA Administrator James Beggs and the Director General of ESA, Dr. Reimar Lüst, signed a memorandum of understanding on 3 June for a cooperative programme concerning detailed definition and preliminary design (Phase B) of the Space Station..

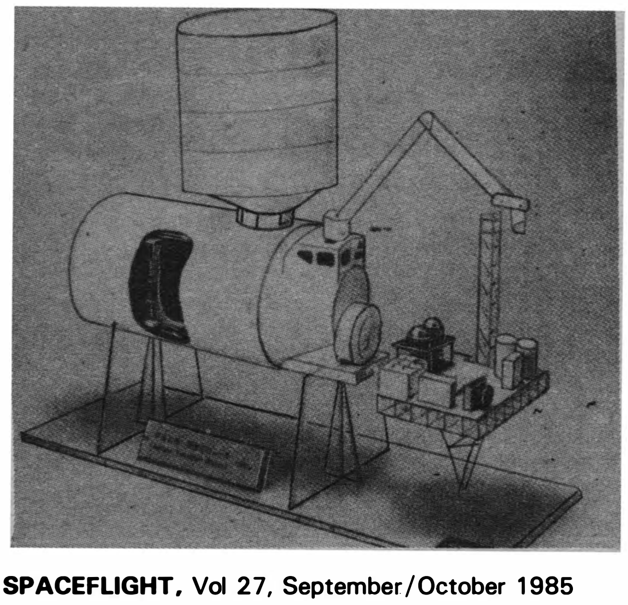
NASA and ESA will conduct and coordinate parallel Phase B studies over the next two years. ESA will study a pressurised module that could be used as a manned laboratory, free-flying experiment platforms for both low-inclination and polar orbits with electric power and cooling and stabilising systems, and a resource module. ESA studies also will cover ground facilities for mission preparation and support and a data transmission system.

The cost of the Phase B studies carried out by European industry under ESA management, together with the corresponding technology programme, amounts to 80 million accounting units. At 1985 exchange rates, the current estimate is $64 million.

NASA signed similar understandings with Japan in May and with Canada on 16 April. Japan will study an experimental module with a pressurised workspace and an exposed work deck. The programme is funded for $5.7 million in Japanese Fiscal year 1985, with the total Phase B funding estimated at $22 million.

In a report published on 10 April by the Japanese 'Ad Hoc Committee on Space Station Program Space Activities Commission,' it was pointed out that the Space Station would provide Japan with direct access to manned space flight technology, with other fields benefitting through technology transfer.

A model of the proposed Japanese Experiment Module. *NASDA*



NASA Administrator James Beggs (right) and the Director-General of Japan's Science and Technology Agency, R. Takenchi, signed an agreement on 9 May in Tokyo for parallel Space Station studies. *NASDA*

At the beginning of this study phase, Japan is concentrating on an Experiment Module that would remain attached to the station. The habitable section would be connected to an open-space experiments platform (as Spacelab platforms/modules operate at the moment) for the main experimental functions. A Shuttle robot arm would be included for flexibility. A logistics section would be carried at 90° to the main body to house experimental materials and consumables, although power, water, communications, etc would come from the main station.

SPACE SHUTTLE

THE SKYNET 4A MISSION

The selection of secondary experiments for the Skynet 4A mission scheduled for June 1986 was formally approved by NASA, the UK Ministry of Defence announced, in June. The prime and back-up payload specialists on the mission, Sqn. Ldr. Nigel Wood and Lt. Col. Richard Farrimond will assume responsibility for the six experiments, for which NASA has allocated one middeck locker.

In the first experiment, radiation effects will be monitored, taking into account the influence of spacecraft shielding and the effect of the Earth's magnetic field. This experiment is directed by the Space Department at RAE Farnborough, the principal investigator being Dr. Clive Dyer, and designed in conjunction with the Instrumentational and Applied Physics Division at AERE Harwell.

The second experiment will study the changes in head and eye movements that occur during adaptation to

Some of the Skynet 4A Shuttle mission experimenters and participants. From left: Dr. C. Dyer, Sqn. Ldr. Nigel Wood, Dr. J. Padday, Dr. H. Ross, Lt. Col. R. Farrimond, Dr. A. Benson and Dr. G. Barnes. *MoD*

microgravity and will include post-flight tests to assess readaptation to normal conditions. The experiment has been devised by Dr. A.J. Benson and Dr. G.R. Barnes of the RAF Institute of Aviation Medicine.

Studying the effect of gravity on the 'wettability' of materials is the aim of the third experiment, which will assess the effect of low gravity on the bonding of adhesives. The principal investigator is Dr. D.A. Tod from RARDE, Waltham Abbey. Two experiments have been devised by Dr. Helen Ross of the Department of Psychology, University of Stirling. The first involves the mass estimation by the payload specialist of moveable objects within the Shuttle and adaptation to weightlessness, using monitoring throughout the mission and afterwards to assess readaptation to gravity. The second will assess the payload specialist's performance throughout the mission and readaptation to gravity afterwards.

The last of the experiments will investigate the effect of the inertial forces of microgravity on the stability of liquid zones, devised by Dr. J.F. Padday of Kodak Ltd.

GALILEO AND ULYSSES CREWS

NASA has named the crews for two Shuttle missions scheduled for 1986. Commanding mission 61F, scheduled for no earlier than 15 May 1986, will be Frederick Hauck. He first flew as pilot on STS-7 in June 1983 and was commander of 51A last November. Primary objective of the mission is the deployment of the Ulysses (International Solar Polar) spacecraft, the first to use the Centaur upper stage.

Other crew members include Roy Bridges, pilot, and mission specialists David Hilmers and Mike Lounge. Bridges was also pilot of the Spacelab 2 mission last July. Hilmers is scheduled to fly as a mission specialist on the Department of Defense 51J mission in September. Lounge was a mission specialist on 51I in August.

David Walker will command the Galileo mission, 61G, set for launch six days after Ulysses with the second Centaur.

Walker flew as pilot on 51A. Other crew members include pilot Ronald Grabe and mission specialists John Fabian and James van Hoften. Grabe will fly as pilot on 51J. Fabian flew on STS-7 and 51G. Van Hoften first flew on the Solar Maximum satellite repair mission, 41C, in April 1984 and then on 51I.

SHUTTLE EMERGENCY

NASA and Chile have been discussing the possible use of Easter Island as an emergency landing site for the Space Shuttle for launches from Vandenberg Air Force Base in California.

Mataveri Airfield on Isla de Pascua (Easter Island) has the potential for serving as a Shuttle Pacific site in the unlikely event of a life-threatening emergency.

SHUTTLE EXPERIMENT MODULE

NASA signed an agreement with Instrument Technology Associates in June for the development of flight hardware for a Standardized Experiment Module payload carrier for use aboard the Shuttle.

The module will be used on a 'turnkey' basis. That is, any commercial firm, government agency, research organisation or educational institution with microgravity experiments can fly them on the Shuttle by purchasing or leasing all or part of the new system.

Under the agreement, NASA will provide ITA with two Shuttle flights to obtain data and validate the design. The first test, scheduled for late 1987, will carry a payload for the Bioprocessing and Pharmaceutical Center of the Philadelphia University City Science Center.

UK SPACELAB PROJECTS

Two scientific instruments prepared in the UK were flown aboard Spacelab 2 in July. They formed part of the 13 investigations that covered a wide range of disciplines, from biology to astronomy, carried on the seven day mission.

Helium abundance in the solar corona and X-ray imaging of regions of the Milky Way were the subjects under scrutiny by the instruments from the Rutherford Appleton Laboratory/Mullard Space Science Laboratory and Birmingham University, respectively.

'CHASE' was the joint Coronal Helium Abundance Spacelab Experiment. After hydrogen, helium is the most abundant element in the Universe, having about 10% concentration by number atoms. Yet, in spite of this, its actual abundance is poorly known - existing measurements lie between 5 and 25%. CHASE, by using a new technique, was designed to determine this value in the solar corona to an accuracy better than one in ten. There are good reasons to believe that the coronal abundance is typical of the Sun as a whole and that the solar abundance will be typical of the Universe in general because it will have been increased only marginally by nucleosynthesis in stellar interiors. Thus the measurement will be directly related to the primeval helium abundance, the concentration produced in the 'big bang' at the origin of the Universe and is therefore an important test of cosmological models.

CHASE consisted of a 2 m grazing incidence spectrometer covering the wavelength range 140-1350 Å, illuminated by a two-reflection grazing incidence telescope. The basic helium abundance measurement was carried out by studying the hydrogen 1216 Å and ionised helium 304 Å radiation re-emitted by the corona through resonance scattering of the bright light at these wavelengths emitted from the solar disc. In other modes of operation, the instruments make detailed studies of the temperature, density and evolution of a variety of other solar structures.

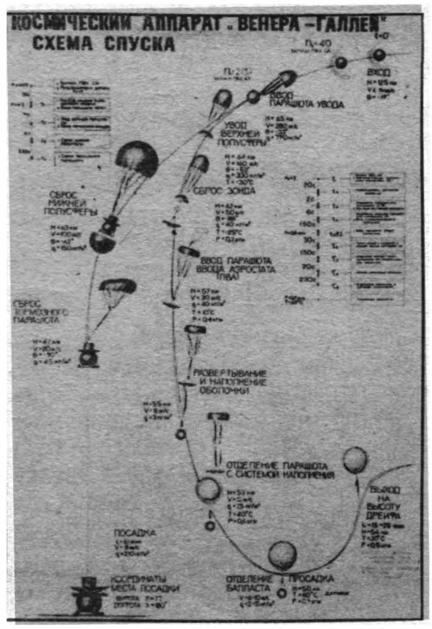
CHASE was mounted with three other experiments for coordinated solar studies on the Instrument Pointing System, supplied by ESA. This assembly of instruments was controlled for much of the time by the payload specialists aboard the Shuttle.

The second UK instrument was the 'X-ray Telescope.' This consisted of two telescopes mounted side by side, carried on their own mount to allow them to point at targets relatively independently of the Orbiter. The telscope was given operational instructions about once per orbit, either by the Spacelab payload specialists or from the payload team in the mission control centre at Houston. It then operated almost automatically until the instructions were updated. The telescope was a large structure and it was essential that its operation should present no hazards to the Orbiter. To ensure that, its entire control system was duplicated, one operating the telscopes while the second monitored its performance, ready to take over if it detected a malfunction.

The telescope's major target was the central region of the Milky Way, obtaining high spatial resolution images of the X-ray sky in the energy range 2.5-24 keV, photon energies not accessible to current X-ray optical systems. By these means, clusters of galaxies may be mapped in the continuum and the iron feature at 7 keV, using this spectral feature as a tracer for non-primordial material. The Galactic Centre, which is heavily obscured by large photoelectric absorption at lower photon energies, can also be examined. The 'coded mask' technique uses an opaque sheet with a pattern of holes to cast a shadowgram of the scene to be imaged on to a position-sensitive detector.

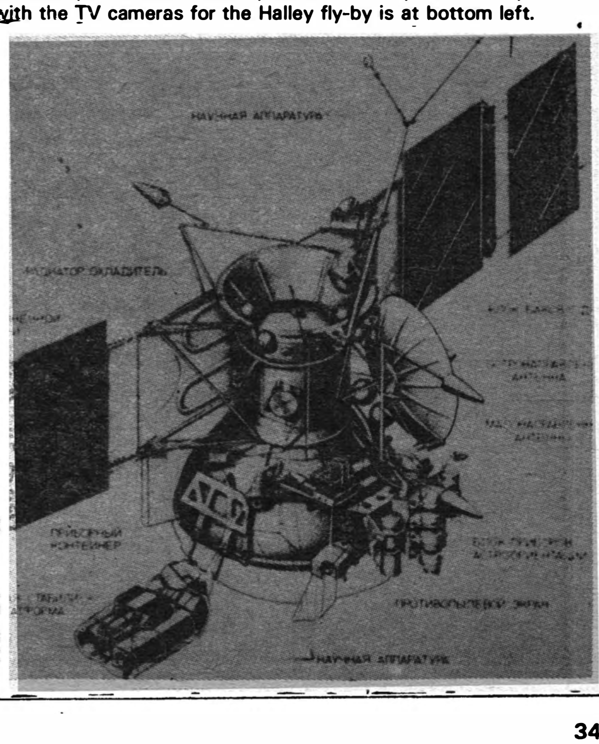
VEGA VENUS SUCCESSES

The two ambitious Soviet Vega probes to Venus and Halley's comet successfully completed the first part of their mission when the two landing capsules and balloons descended to the planet on 11 and 15 June. While the two landers analysed the surface (no cameras were carried), the two balloons floated some 50 km high over one-third of the planet on the night side, each relaying 46 hr of data on temperature, pressure, vertical wind speeds, cloud density and brightness. Preliminary tracking results yield a wind circulation speed of 250 km/hr and an altitude of 55 km. It was expected that the 3 m diameter helium-filled balloons would burst as they crossed on to the daytime side but it appears that the batteries in the 6½ kg instrument gondolas suspended 12 m below the spheres gave out first.



A Soviet diagram showing the descent sequence for the Vega landers and balloons.

This is how the two Vega main sections appear now that the descent spheres have been separated (from top). The scan platform with the TV cameras for the Halley fly-by is at bottom left.



ORBITAL REFUELLING

The Orbital Refuelling System was first flown on Shuttle mission 41G to demonstrate fuel transfer and management techniques, as preliminary work in the development of a space tanker for the replenishment of propellant and other liquid consumables on satellites, writes Nicholas Steggall.

Since current satellites are not designed for in-orbit refuelling, special techniques are having to be developed. Although the ORS is a prototype unit capable of multiple transfers of 100 kg of hydrazine, it can be modified to deliver 230 kg to an orbiting satellite through a line connected by a space-walking astronaut (during 41G this was done by David Leestma and Kathryn Sullivan). The preliminary test last year transferred liquid hydrazine from one tank to another within the ORS, using commands from the orbiter's aft flight deck.

An operational system is envisaged by mid-1987 capable of transferring 340 kg of propellant, eventually rising to 2500 kg by around 1990 - a Request for Proposals was issued to industry in April 1985 for the larger proposal.

SATELLITES

NOAA 8 RECOVERY

The recovery of the 'presumed dead' NOAA 8 weather satellite in May increased the odds for saving the lives of people whose planes have crashed or whose ships are in peril. The search and rescue (Sarsat) equipment was able to resume its operation of picking up distress signals.

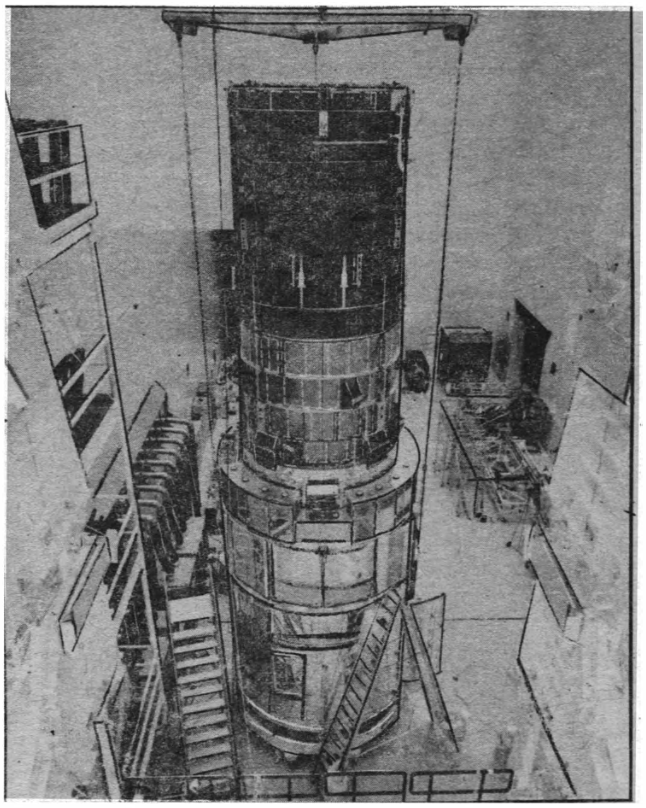
According to Gerald Longanecker, Meteorological Satellites Project Manager at NASA's Goddard Space Flight Center, 'the restabilisation of the satellite, which began tumbling out of control last June [1984] when an oscillator in the attitude control system failed, is now in full operation with the exception of one detector on an infrared radiometer that measures temperatures from the Earth's surface to 25 miles altitude. The instrument has three detectors, however, and the loss of one means only a minor loss of data.'

Ground controllers reacted swiftly to stabilise the satellite when a backup oscillator came back on line unexpectedly.

The success means that the search and rescue equipment will resume operations as part of an international programme that began in September 1983. Up to May 1985, almost 400 lives had been saved. During the 11 months of the NOAA 8 malfunction, three Soviet and one US satellite provided the coverage. With only one satellite in operation, for example, a person in trouble could expect a satellite pass only once in 12 hours. With four in orbit, a pass can be expected every four to six hours. A fifth satellite helps to fill in some of the gaps.

CHECKOUT CONTRACT

The new European Remote Sensing satellite (ERS 1) and its payload designed to provide data for long-range weather forecasting are to be built under the checkout of two British supermini-computer systems made and networked by Information Technology Ltd. The order, worth £440,000, was placed with the company's Aerospace Branch, who recently announced the formation of a British consortium to offer turnkey checkout systems for European satellites.



The Hubble Space Telescope is reported to be still on schedule for launch by the Shuttle next summer. *NASA*

ESA BORROWS GOES 4

The US has loaned ESA one of its standby geostationary weather satellites (GOES 4) as a temporary substitute for Europe's Meteosat 1. Launched in 1977, Meteosat has long exceeded its original three year lifetime and it has now run out of station-keeping fuel; it drifted out of view of ESA's ground station network in July.

GOES 4, which was located at 140°W longitude over the Pacific Ocean, was moved westwards by 4° a day to bring it to its new position at 10°W longitude above the Atlantic Ocean in mid-June. Since ESA ground equipment is not compatible with the GOES 4 command system, the US National Oceanic and Atmospheric Administration is operating the satellite for ESA from its satellite guidance facilities at Suitland, Maryland and Wallops Station, Virginia. Data are being received at ESA's Meteosat Ground Facilities at ESOC in Darmstadt.

OTHER NEWS

THE FUTURE FOR ARIANESPACE

Arianespace, the launcher company with 36 leading aerospace companies in Europe as its shareholders, confidently predicts that it will maintain its significant share of the commercial launch market, Frédéric d'Allest, the company's Chairman, recently told *Spaceflight.*

The company's Ariane rocket, taken over from the European Space Agency following the 10-long development and promotion series, today has captured almost half the world's commercial satellite launching market. Predictions for 1987-1991 suggest that around 150 commercial satellites, most of them for communications purposes, will be looking for boosters. Arianespace's goal is to handle at least one-third of them. The company had a

pre-tax profit of Fr 30 million in 1984 and expect to go well above that in 1985.

A healthy company clearly cannot remain stationary in the launcher market since satellites are growing and the competition is expanding. Ariane and Shuttle now directly face each other in the communications sector - a prime factor in NASA holding down the price increases being recommended to President Reagan - but more launchers will gradually come on to the market. The American Delta and Atlas-Centaur expendables have been handed over to commercial operators now that NASA no longer needs them, while Japan is developing its powerful H2 vehicle, equivalent to the Ariane 4 model with a possibility of being uprated to compete with the Ariane 5.

The Ariane 3 version is now on the scene, having entered service on 4 August 1984. Ariane 4 will make its debut next year in the first of six variations. With the second launch pad at Kourou coming on stream this year, Arianespace will be able to handle 10 vehicles per year, compared with their target of 6-8 for their reasonable slice of the market.

Ariane 4 will take Europe into the 1990's in terms of launch capability. Ariane 5, a completely new vehicle yet to be decided upon, could begin operations in 1995. That will satisfy demand into the next century.

WALLOPS ANNIVERSARY

NASA's Wallops Island facility in Virginia, one of the oldest rocket ranges in the world, celebrated 40 years of operation on 4 July. The first research rocket, a 5 m Tiamat, was launched from the Island on 4 July 1945.

The Island obtained its name about 300 years ago from John Wallop who was appointed Deputy Surveyor of Virginia by Col. Edmund Scarburgh in the 17th Century and was granted a patent in 1672. Since its origin as a scientific research range, Wallops has launched some 13,000 rocket-propelled research vehicles and conducted thousands of aeronautical and aircraft tests. The breakthroughs to supersonic flight by aircraft and to hypersonic flight by rocket systems were largely attributed to fundamental aerodynamic research conducted at Wallops with aerodynamic models propelled by multiple stage rocket systems. Technology development for the manned programme, such as manned capsule escape techniques and maximum dynamic pressure tests for the Mercury Project, were conducted at Wallops. Scientific discoveries that later led to synoptic measurements by satellites were made by sounding rockets, many of which were launched from Wallops or from remote locations by Wallops teams.

Wallops is now known as a centre for the NASA Suborbital Programs. Sounding rockets, balloons and aircraft are used to conduct space science and aeronautical research at Wallops and various other locations.

ANTENNA MOVES TO TASMANIA

NASA has donated a 26 m antenna located at the Orroral Valley Tracking Station in Australia to the Australian University of Tasmania.

The station ceased operations in December 1984 after use in a variety of programmes including Skylab, Apollo-Soyuz and the Shuttle.

The University of Tasmania's physics department, one of Australia's major centres for astronomy and astrophysics, will use the antenna as part of its teaching and research activities. One of its planned uses is in operation with the telescope presently under construction in New South Wales.

It will also be available for 'very long baseline interferometry' in conjunction with other instruments. This is a system that uses a number of separate antennae to construct a radio telescope with high resolution. Using the antenna for interferometry will assist geodynamics and geophysical research by obtaining more accurate measurements of the Earth's surface and will contribute to the data base on the Australian continent.

MILESTONES

May 1985

1 Voyager 2 is 341 million km from Uranus; encounter is planned for 22 January 1986.

7 *Challenger* lands in California to end the 51B/Spacelab 3 mission after 7 days and 49 orbits.

7 A third UK Skynet 4 military communications satellite will be built by British Aerospace.

7 The US GOES 4 weather satellite is loaned to Europe to replace Meteosat 1.

8 Ariane V13 successfully launches the Telecom 1B and Gstar 1 communications satellite (the fourth type III launch).

9 NASA and Japan sign an agreement for Space Station Phase B studies.

9 The second test of an Ariane 4 liquid booster is successfully carried out in W. Germany.

16 ESA accepts Giotto after a 2-day final review. Launch is due on 2 July.

17 The Soviets will launch a Mars orbiter/Phobos *landing* probe in 1988, Novosti announces.

24 NASA and Hughes agree to attempt a Leasat rescue during Shuttle mission 51I.

27 The boosters for the Soviet large shuttle are experiencing development trouble, it is reported.

June 1985

3 NASA and ESA sign a 2-year agreement on Space Station Studies.

4 NASA announces the selection of 13 new astronauts, bringing the total to 103. Six are pilots and two of the seven mission specialists are women.

6 Soyuz T-13 with Vladimir Dzhanibekov and Viktor Savinykh is launched at 06.40 GMT, docking with Salyut 7 on 8 June at 08.50 GMT.

11 The Vega 1 capsule lands successfully on Venus; a balloon is ejected into the atmosphere. Vega 2 follows on the 15th. The main sections continue on to Halley's comet.

18 *Discovery* is launched at 11.33 GMT with a seven-man crew to begin Mission 51G (the 18th flight). It lands on the 24th at Edwards AFB.

23 Progress 24 docks with Salyut 7/Soyuz T-13.

July 1985

2 Giotto is successfully launched by Ariane from Kourou.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

SPACE: THE LONG-RANGE FUTURE

Part 1

By Jesco von Puttkamer*

The next major US space programme is the permanent Space Station, due to begin operations in the early 1990's. As the author points out, it is really just the beginning of a breathtaking array of possibilities for future space ventures.

Introduction

When President John F. Kennedy reviewed the potential space goals in 1961 for a major new national initiative his options were generally limited to an Earth-orbiting space station and a manned mission to the Moon because, as NASA Administrator James Webb, Defense Secretary Robert McNamara and Vice-President Lyndon B. Johnson argued [1], 'it is man, not merely machines, in space that captures the imagination of the world.'

By Year 2000, with a fully grown low-Earth orbit (LEO) Space Station and its orbital transportation, habitation and operations infrastructure in place, the number of options for long-range goals in space will be considerably larger. In addition, because the rationale for undertaking major space projects will have to consider numerous other arguments - such as scientific, industrial, commercial, international, etc. - besides the quasi-symbolic boost to national prestige that motivated Apollo, the job of selecting and coordinating between them will be considerably more complex.

This is because the existence of the Space Station will not only *enhance* Earth-orbital and deeper-space ventures but also (as a unique space research and development facility, operations base and transportation node) *enable* entirely new initiatives for human advancement in space not possible before. Unlike the era of the Kennedy decision, when there was little choice, the 'name of the game' in the post-Space Station era is clearly 'options' and 'multiple objectives' because of the permanent presence of humans in orbit in a position analogous to a beachhead on a new continent, with all the manifold possibilities of further progress inherent in such a staging point.

These possibilities suggest the Space Station as a logical next step in Mankind's socio-technological evolution [2]. If space is regarded as a frontier, the Space Station is a focal point for exploration and development, as an operations base for the continued exploration of the unknown and as a major ingredient for expanding human knowledge.

To look at the long-range future beyond the Space Station is equivalent to asking: what are these manifold possibilities? It is also clear that the constraints are set by the limits of our imagination.

Human Evolution and Roles in Space

In the long-range view (Fig. 1), our increasing capability in space will advance in three major successive phases:

1. Easy access to and return from space;
2. Permanent presence in low Earth orbit (LEO); and
3. Limited self-sufficiency of man in space.

* NASA Headquarters, Program Manager, Long-Range Studies, Office of Space Flight. Opinions contained in this paper are those of the author and do not necessarily represent official policy of the National Aeronautics and Space Administration.

Table 1. Useful Attributes of Space

- **Weightlessness** (facilitâtes: special manufacturing activities, construction of very large delicate structures, and reliability of operations)
- **Easy Gravity Control**
- **Absence of Atmosphere** (unlimited high vacuum)
- **Ability to Utilize Materials/Elements** that cannot exist in Earth's atmosphere (such as alkali metals, sodium, phosphorus, calcium, etc)
- **Comprehensive Overview** (of Earth's surface and atmosphere, for: communication, observation, power transmission and other applications)
- **Isolation** (from Earth's biosphere, for hazardous processes: little or no environmental, ecological or 'localism' issues)
- **Readily Available Light, Heat, Power** (10 times rate on Earth)
- **Infinite Natural Reservoir** (for disposal of waste products and safe storage of radioactive products)
- **Super-cold Temperatures** (infinite heat sink near absolute Zero)
- **Large, Three-dimensional Volumes** (storage, structures)
- **Variety of Non-diffuse (Directed) Radiation** (UV, X-rays, gamma, etc)
- **Magnetic Field**
- **Availability of Extraterrestrial Raw Materials** (on Moon and asteroids)
- **Avoidance of Many Earth Hazards** (Storms, Earthquakes, floods, volcanoes, lightning, unpredicatble temperatures and humidity, intruders, accients, corrosion, pollution, etc)
- **Potentially Enjoyable, Healthful, Stimulating or Otherwise Desirable for Human Well-being.**

The development of the Space Shuttle/Space Transportation System (STS) for transportation and of the initial Space Station for orbital habitation and experimentation provides the main elements of the infrastructure of Phase 1, to be accomplished by the end of this decade. But permanent manned presence requires considerably more: an orbital operations capability of a scale large enough to respond adequately to the projected socio-economic needs of the 1990's. Phase 2 will add the capability of manned access (sorties) to geostationary orbit (GEO) and the operational deployment of large space structures. To become more autonomous in space, Man must proceed to develop closed-cycle life support systems and larger-scale industrial applications in space which, in Phase 3, should lead to closed ecological systems (including space-grown food), construction, industrialisation and access to extraterrestrial materials.

Progress towards a permanent human presence in space is shown in Fig. 2. Listed are the total man-hours in space accumulated by astronaut crews in each of the five past major US programmes as well as the times spent on extravehicular activities. With a permanent presence, the man-hour count for STS/Space Station becomes indefinite [3].

To suggest possible future development scenarios, we must first establish points of reference. What will our situation in space be by Year 2000; that is, when Man, after reaching the current goal of easy access into and

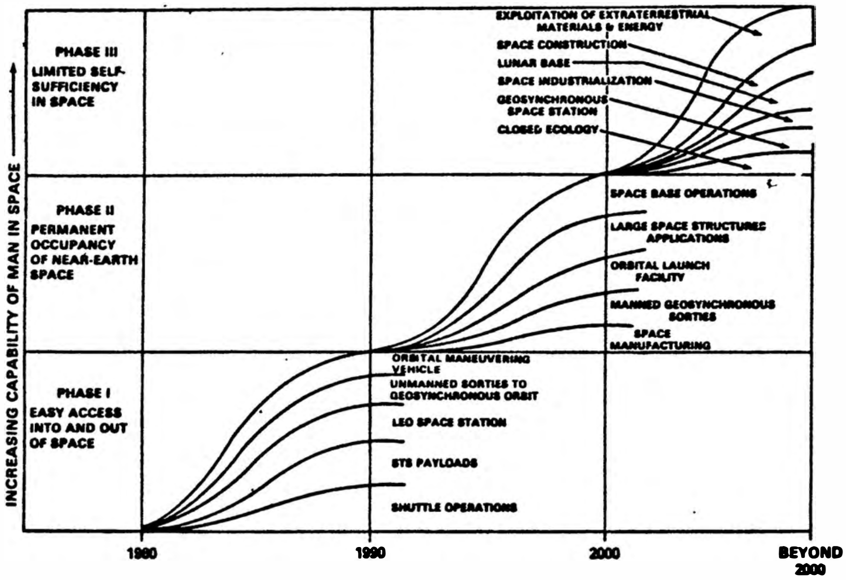


Fig. 1. Man's progress in space.

Fig. 1a Relevance tree for the future of the Space Programme.

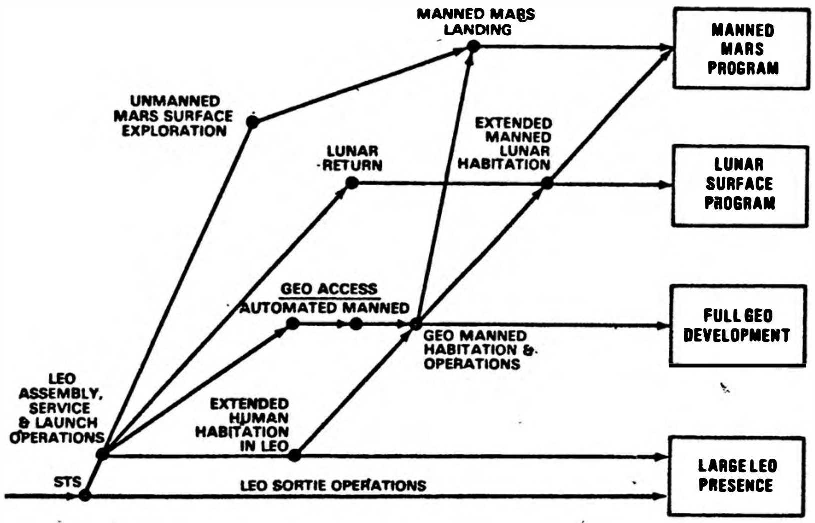
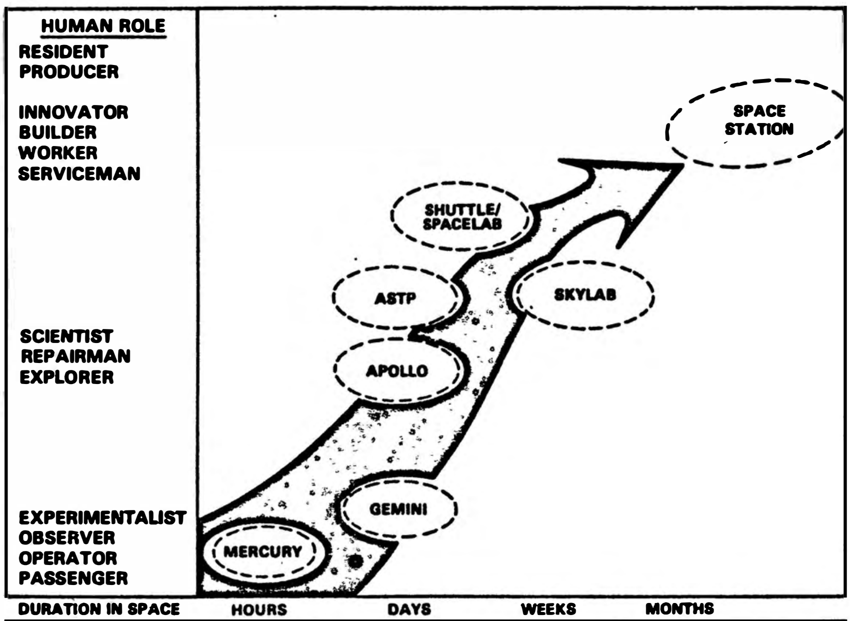
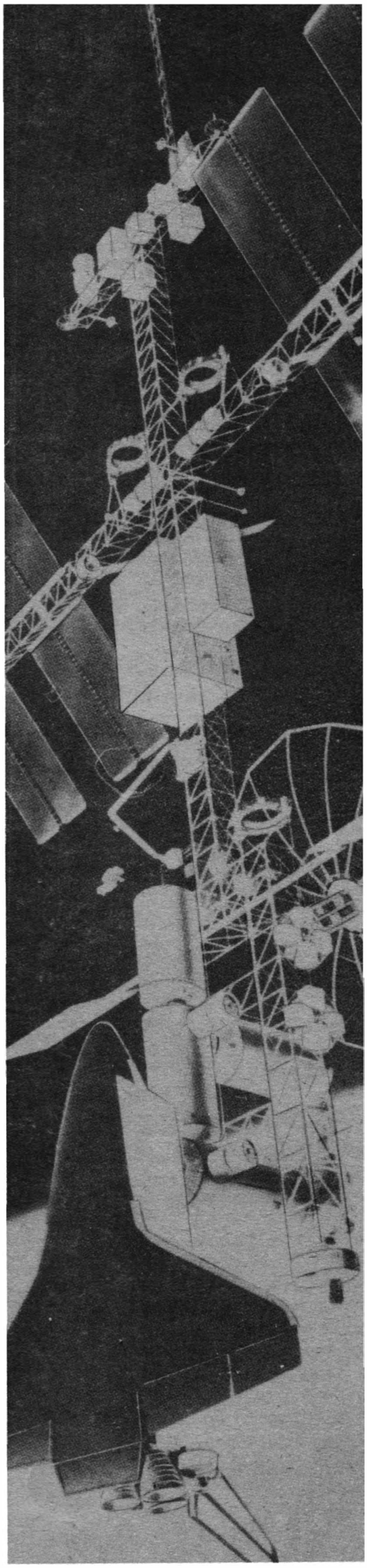


Fig. 2. Evolution of Man's role in space.



	MERCURY	GEMINI	APOLLO	SKYLAB	ASTP	SPACE STATION
TOTAL MANHOURS	54	1940	7560	12,351	662	INDEFINITE
EVA MANHOURS		12	168	82		INDEFINITE



out of space, has also accomplished Phase 2 as discussed above?

Plateau of Departure: Space Infrastructure Year 2000

First, what are the most significant space resources that provide the main motivation behind the Space Station, its infrastructure and its subsequent further growth? A listing of the major attributes of space that make it attractive for industrialisation, is given in Table 1 [4,5].

Since future progress in space is intrinsically connected with progress in many key technologies [5], particularly for the *manned* operations now being envisaged (such as space laboratories, platforms, bases, industries and, over the long term, settlements) it is appropriate to assess space technology itself, based on past experience and projected out to Year 2000. This is attempted in Table 2 [5,6].

The rapid growth in commercial technologies such as communications channels, viewing resolution and launch cost clearly suggests that space in the years around and beyond 2000 will become a burgeoning frontier for the development of an increasing number of industrial and commercial ventures in LEO and GEO. Assuming that the world expenditure on all space developments was roughly $20,000 million in 1983, an annual growth of only 2% would amount to investments of $75,000 million annually in 2050 and $202,000 million in 2100 (1983 dollars). For a somewhat more optimistic scenario of 8% growth, however, the annual investment in space would reach an outstanding $3.5 million million [5].

Given the above projections, at Year 2000, from the viewpoint of transportation, habitation and operation, we will be able to operate routinely with flight crews (that is, safely, successfully, on schedule and economically) not only between Earth and LEO, as the Shuttle will allow us to do soon, but also at geostationary orbits (GEO), between orbits and eventually at lunar and planetary distances.

Taking this 'Year-2000 capability' as a starting position for a long-range view, the basic Space Station infrastructure will require augmentation by the end of this century to:

1. Support large permanent facilities for science, research and development, commerce and operations in LEO and GEO;
2. Provide routine, economical and flexible access to all orbits by men and robotic systems;
3. Institute routine checkout, refuelling, repairing and upgrading of space facilities as well as debris removal in all orbits to GEO, and
4. Devise and implement innovative STS uses and missions such as large space tether applications for power generation, non-propulsive transportation and satellite constellations.

By 2000, an evolutionary cryogenic concept of the Orbital Transfer Vehicle (OTV) family will provide reusable manned flights to at least GEO. However, this system could also be the basis for extended transportation for a lunar base and for such planetary projects as a robotic Mars Sample Return Mission. Other planetary exploration missions have been identified by the Solar System Exploration Committee (SSEC) of the NASA Advisory Council. They include a recommended Core Program [7] of Venus Radar Mapper, Mars Geoscience/Climatology Orbiter, Comet Rendezvous and Titan Probe missions, as well as more advanced missions such as Mars Surface Science, Mars Sample Return and Comet Sample Return that are not included in the Core Program.

OTV, supplemented at times by a remotely-controlled

Table 2. Progress in Space Technology, Past and Projected

System	1960	1975	1990	2000
Payload capability (lb)	25	250,000	80,000 (reusable)	10^6 (reusable)
Communications channels	15 (LEO)	15,000 (GEO)	10^5 (GEO)	10^7
Communication bit rate (Mars-Earth)	8	10^5	10^7	10^9
Man days/mission	0.1	250	10^5	5×10^5
Resolution (km)	5 (LEO)	0.1 (LEO)	0.05 (GEO)	0.02 (GEO)
Data storage on-board (bits)	5×10^5	2×10^{10}	8×10^{12}	16×10^{13}
Energy storage (kW-hrs/lb)	0.02	40	800	1200
Active circuits (per cubic inch)	4	120,000	5×10^8	10^{10}-10^{12}
Space-borne computer speed (operations/sec)	2×10^3	5×10^5	3×10^7	10^8-10^9
Launch costs (1984$/lb to LEO)	20,000	3000	1000	100-300
Position error (m)	1000	50	0.1	0.02
Failure rate (No./hr/Mbits)	10^{-2}	10^{-4}	10^{-6}	10^{-7} - 10^{-8}

Note: Adapted primarily from NASA's Outlook For Space Report, SP-387, 1976.

Orbital Maneuvering Vehicle (OMV) with special kits for remote servicing, tanking and debris capture, will be able to fly with or without crews with minimum change. Since servicing, maintaining and refuelling these reusable vehicles will be better done in orbit rather than on the ground, the Space Station must then be equipped with suitable hangar, servicing, storage and tanking facilities.

By Year 2000, missions made possible by the Space Station will require routine operation of unmanned cargo-carrying Earth-to-LEO vehicles with larger payload diameter, greater lift weight and/or lower cost-per-kg capability than the Space Shuttle.

At the end of this century commercialisation of materials processed in space is expected to be at an advanced level, leading to manufacture facilities in space. Among those areas that currently appear to hold the greatest promise are pharmaceutical products, high purity advanced semiconductors and unique glass materials and glassy metals.

Besides the various advanced systems, tools and techniques necessary for routine servicing throughout the LEO/GEO/Cislunar space utilised by satellites and spacecraft, for an improved permanent manned presence we must also have augmented crew and life support systems. These would have to provide, for the long range beyond 2000, closed-cycle, regenerative operation (water and air loops) of on-board environment control and life support (EC/LS); regenerable space-maintained extravehicular EC/LS backpack systems; advanced high-productivity mobility systems; Earth-norm food, hygiene and interior habitability standards (the latter flexible to allow the growth of new 'space-culture' standards); and advanced on-board automation to handle tasks that do not necessarily require continued manned attendance, while being flexible enough to allow easy upgrading as electronics, avionics and robotics technologies advance rapidly.

Beyond 2000: Mission Spectrum - General Trends

Beyond Year 2000, the long-range scenarios will be

Table. 3. Post-Space Station Mission Goals

Benefits	Type*	Domain Involved
SCIENCE AND EXPLORATION		
Determine origin and early history of Solar System	I	LEO and other Solar System science
Understand galactic structure and dynamics	I	LEO and other Solar System science
Understand cosmology	I	LEO and other Solar System science
Verification of physical laws	I	LEO and other Solar System science
New resources from space	M	Lunar surface/Mars moons/asteroids
COMMERCIALISATION		
Optimise industrial activity	M	LEO and GEO operations
Hazard removal	M	LEO, GEO and cislunar operations
Energy from space	M	GEO and cislunar operations
New resources from space	M	Lunar surface/Mars moons/asteroids
EARTH APPLICATIONS		
Agricultural, forestry and fishery management	M	LEO and GEO operations
Protection of Environment	H	LEO and GEO operations
Aid to individuals in peril	H	LEO and GEO operations
Aid to crime control	H	LEO and GEO operations
Aid to internal security	H	LEO and GEO operations
Improved Government	H	LEO and GEO operations
Energy from space	M	GEO and cislunar operations
New resources from space	M	Lunar surface/Mars moons/asteroids
International cooperation	H	LEO and GEO ops/lunar base/Mars missions
EXPANDING PRESENCE		
Space habitation	M	LEO and GEO ops/lunar base/Mars missions
New technological capabilities	M	LEO operations
New resources from space	M	Lunar surface/Mars moons/asteroids
Hazard removal	M	LEO, GEO and cislunar operations
International cooperation	H	LEO and GEO ops/lunar base/Mars missions
Promotion of international peace	H	LEO and GEO ops/lunar base/Mars missions

* I = Intellectual M = Materialistic H = Humanistic

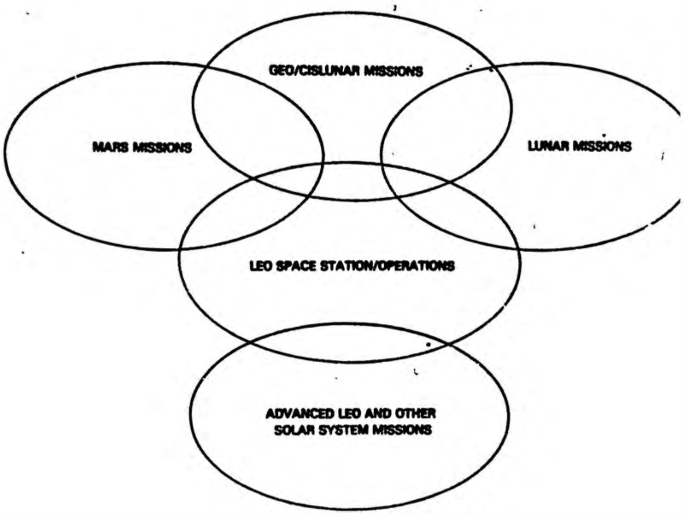


Fig. 3. Post-Space Station mission domains.

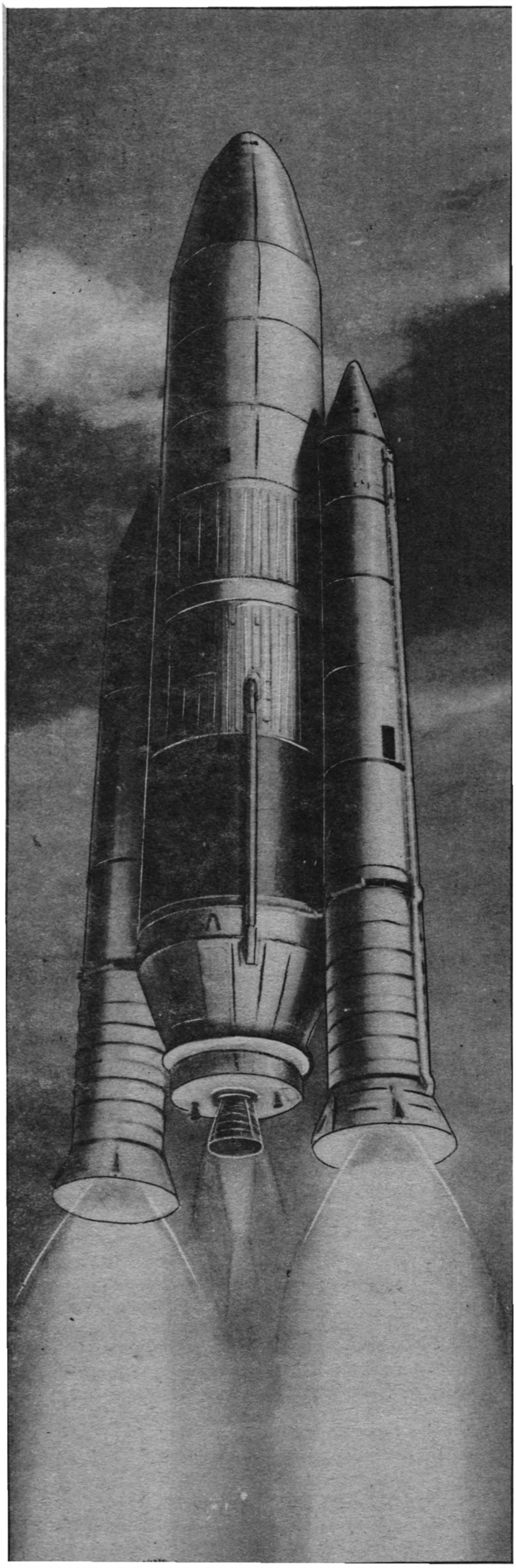


Fig. 3a (right). A 1983 Boeing concept for the Shuttle Derived Launch Vehicle (SDLV).

made possible by the Space Station: Exploration, Commercialisation, Earth Applications and Expanding Human Presence as well as sustained Space research and development for innovative systems and techniques currently not available, not understood or even not yet known. Table 3 examines these potential mission goals; included are the most likely space domains involved to meet these needs.

The major manned and automated space missions that would satisfy these goals and that would provide unprecedented scientific/technical benefits can be envisaged in all regimes of space accessible to us by Year 2000: LEO, GEO and other high-energy orbits, lunar orbit and lunar surface, and at the distances of the inner and, later, outer planets.

Visions beyond Year 2000 must include a mission spectrum with programmes such as a complex of advanced scientific and industrial facilities in LEO, permanently manned scientific and communications facilities in GEO, a permanent base on the Moon, a manned expedition to Mars, etc. All offer opportunities for international participation. In each case, the LEO Space Station and its infrastructure would serve as the research and development facility and staging base with a maximum degree of commonality and modularity. But since this infrastructure and its future capabilities are evolutionary, there should be continual 'parallel' (instead of 'sequential') study of the requirements imposed on these novel capabilities by the future programmes. The various space domains cannot be isolated from each other; they 'overlap' and are mutually dependent (Fig. 3). No longer will the future be as straightforward as it seemed at the time of the Apollo decision. The complex mission spectrum that now becomes possible, and its cost, will be affected deeply by the network relationships and synergisms between programme and mission systems, design elements and technologies.

Increasingly in the long range, we will also see an era of growing robotics capability, of automation systems working in space along with humans helping to improve our life on Earth and pursue further challenges in space. With the establishment of a permanent manned presence there will be a place for both men and 'intelligent' machines in space and, through technology transfer, on Earth. Machines will certainly not replace humans in space but they will free us for more productive undertakings. While artificial intelligence systems will not have a major impact on the initial Space Station design for the early 1990's, an evolutionary Station should be designed with the future availability of highly autonomous intelligent machines in mind [8]. People and machines in space will demonstrate new types of interactions and will thrive, not just survive. From the first stages of planning and design, they must be viewed as an integral system.

The number of people who could be involved, along with machines, in space industrialisation and other ventures may depend to a considerable degree on transportation costs. Indeed, as transportation costs decline the optimum division of labour between humans and robots should shift toward an increasing demand for humans. The industrialisation of space will not only create new markets and more jobs on Earth but many of the space industries of the decades ahead will also require highly qualified workers in habitable orbital facilities.

LEO Regime Beyond 2000

If we start our preview of post-Space Station programmes beyond Year 2000 at the LEO regime, the optimum balance between the numbers of technicians taken into space and the amount of automation will be determined by the space science, exploration and industrialisation ventures underway. But, as Brown has pointed out [5], there is at least one aspect of the expected developments that seems almost ready to begin; it would inherently attempt to maximise the presence of people: space tourism [9]. Current estimates by one commercial company with experience in 'adventure tourism' of the price of a seat on a Shuttle Orbiter modified for passenger transportation run between \$2 and \$3 million and it is believed there will be a worldwide market for 300-350 passengers a year at this price during the second half of the 1990's. This market will grow explosively as transportation costs decline as indicated in Fig. 4 [5], and as average personal income continues to rise about 1-2% annually as it has in the past.

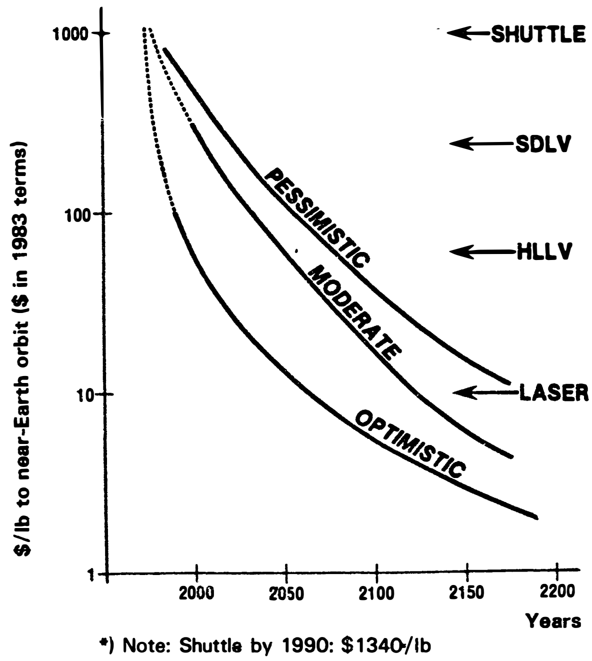


Fig. 4. Transportation costs to near-Earth orbit.

Brown has identified a number of critical factors likely to affect the pace of future investments in space in a major way [5]:

1. Successful Technology: Declining transportation costs to LEO, efficient OTV engines, orbiting space bases, and profitable space industries, increasingly reliable and 'intelligent' robots, lunar base, planetary space stations and settlements.
2. Tourism: 'Inexpensive' safe transport, space hotels, hospitals, convention centres, exciting journeys.
3. Favourable Health Expectations: Physical/mental/emotional, longevity.
4. Attitudes on Earth: Increasing private investment, national enthusiasm, international cooperation and peaceful competition.
5. Quality of 'Frontier-Life': Favourable social dynamics, benign politics, rapid economic growth.

The fourth is related to some of the social and/or political driving forces on Earth [5]. These may be considered on three levels. First, commercial space activities must show at least a reasonable potential for becoming profitable. Whether financed privately, by quasi-public institutions or by governments, they will need to be seen

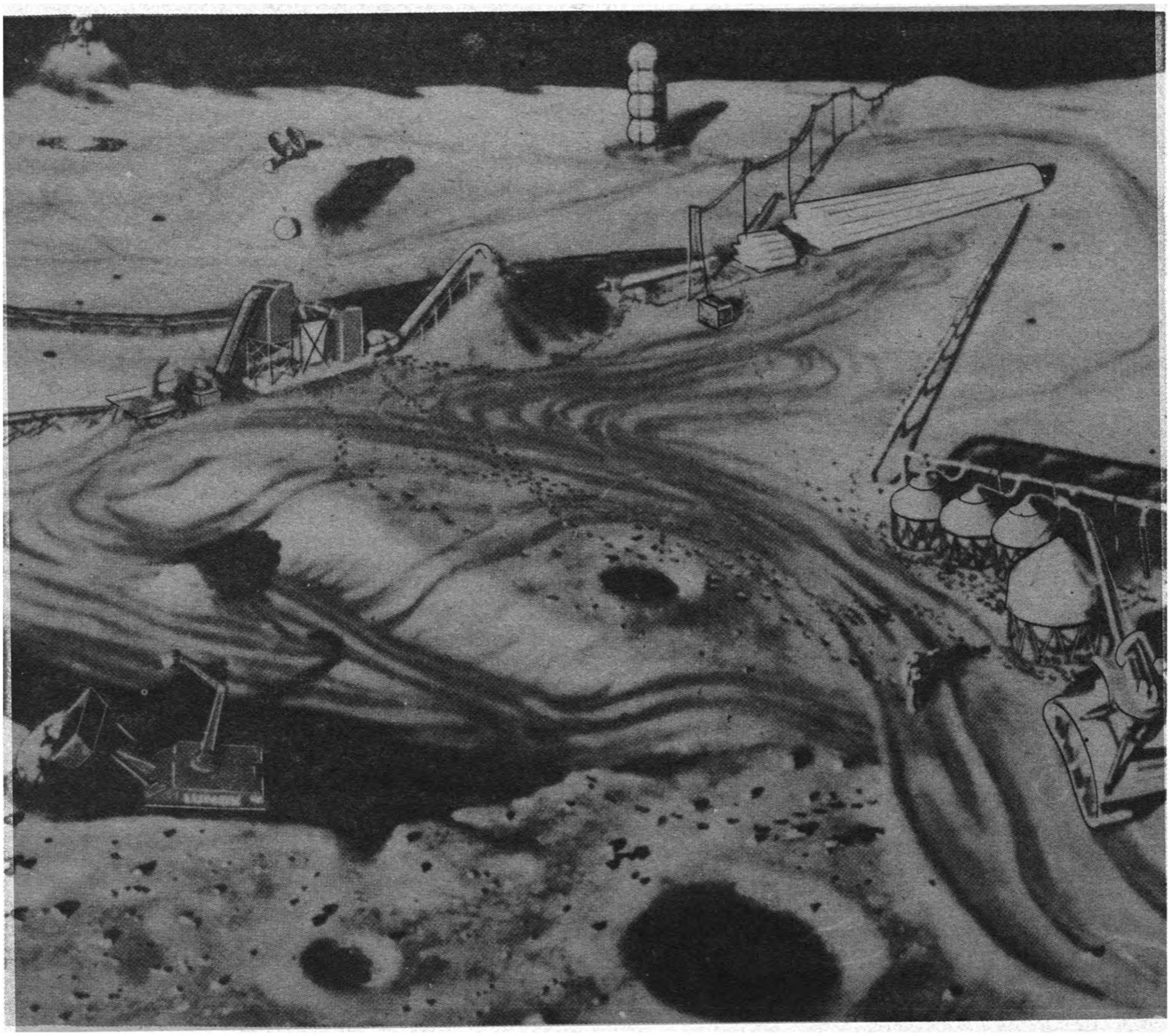


Fig. 4a. Lunar operations will play an important part in future space programmes. This is a 1983 concept focussing on lunar mining operations for the production of oxygen. Robot loaders scoop the soil into the processing facility in the centre to extract oxygen for storage in the modules at right. The liquid oxygen can then be shipped into space to be used as propellant, cheaper than lifting it from the surface of the Earth. *NASA*

as profitable investments if they are to receive the required capital infusions for prolonged growth. Even as little as a 2% annual growth could provide huge space-based investments in the 21st century. In addition, as shown on Fig. 4, by the late 21st century or early in the 22nd century, transportation costs alone may well be lower by a factor between 20 and 50 from those of today. When that factor is coupled with the expected miniaturisation of electronics, advances in artificial intelligence, automation, versatile robots, the availability of materials from lunar and other extraterrestrial sources, relatively maintenance-free designs, etc., it is clear how difficult it is to visualise today what array of projects will be commonplace 100 years or more in the future that would require annual investments of a million million dollars or more.

The second driving force for near-term space development is related to national enthusiasm. Whether or not the commercialisation of space is profitable and rapid, many aspects of space exploration and development are known to be extremely important for basic scientific knowledge. Many spinoffs will provide valuable innovations. National pride in such accomplishments is a significant factor. Prolonged national enthusiasm appears to be an important prerequisite for a relatively optimistic long-range space scenario [5].

The third driving force, and one of potentially great importance over the long term, is the requirements for both international cooperation and peaceful competition in space ventures. For example, many space developments will be very expensive if they are to be accomplished over the next several decades. The costs are so large that unless several nations participate over a relatively long period the project could be postponed almost indefinitely. It is easy to envisage that cooperation would become essential for some of the more expensive projects.

Routine Space Station operation involving assembly and launch, retrieval, maintenance and repair will enable the growth of very large science projects in LEO in such disciplines as Earth and life sciences, astronomy and astrophysics. Of particular significance for the latter two are the Station-supported assembly and occasional tending of a 10 m optical telescope as a follow-on to the current Space Telescope, a large X-ray facility as the next step beyond the current AXAF, a 100 m infrared/submillimetre telescope as the next step in Large Deployable Reflector evolution and a high-energy astrophysics laboratory as follow-on to the HEAO satellites.

In the years of the early 21st century, very useful large-scale science activities and applications services will be accomplished in LEO space. The ultimate location for the

most effective utilisation of a manned space system, however, appears to be at GEO.

GEO/Cislunar Regime Beyond 2000

A geosynchronous site has extremely attractive features such as continuous direct line-of-sight to large areas on Earth, almost constant viewing to study celestial objects and the Sun, an inherently stable orbit and maximum avoidance of Earth albedo and occultation.

For these reasons, there would be a science and applications complex at GEO containing facilities for communications, Earth-pointing observation, navigation, tracking, astrophysics and solar-terrestrial observations. The communications facility would include large antennae with flexibility for switching between beams/antennae to permit efficient use of the frequency spectrum, and smaller less complex ground terminals than those of today. Because of the new capabilities of assembly, repair, maintenance and checkout activities in space, it will be possible to make satellites much larger and more complex. In a reversal of present practice, the user equipment on the ground can be made tiny, simple, highly portable and inexpensive. This principle of *complexity inversion,* which is the key to making space flight directly beneficial and affordable to users, including the 'man in the street,' was put forward in a study for NASA in 1976 [10].

From geosynchronous altitude, missions of Earth-based users can be serviced by one or only a few satellite platforms. Because of their increased size and complexity, these satellites will be able to perform functions impossible with simpler and smaller satellites. Owing to weightlessness, it will be practical to assemble much larger antennae, reflector structures and science platforms than those we now have in orbit. Typical multi-beam antennae for radio frequency and microwave output could be from 70 to 200 m in diameter, and passive space reflectors for beaming light to Earth or relaying energy to space-based users could reach diameters 300-1000 m.

The new, almost unlimited opportunities offered by space communications using these advanced GEO systems in the beyond-2000 era have the potential to satisfy many serious needs of Mankind. For example, improved educational opportunities would become available with a large, high-power and direct-broadcast satellite bringing televised programmes to mountainous, rural and remote areas. Multibeam satellites could provide jam-proof communications from any location [10].

Improved public and governmental services will be obtained by using multibeam satellites for direct and immediate communications to disaster areas. These satellites would also provide a way of holding direct and instantaneous votes and polls. They can improve national security and international air/sea traffic control; low-frequency loop antennae can provide global communications with ocean vessels; and 24 hour, all-weather monitoring of global air and ocean traffic can be accomplished with a large microwave antenna satellite. Public-service satellite systems will also be used to provide services such as wide-area health care, teleconferencing, electronic commuting, news services and search and rescue [10].

High-resolution Earth observation devices could continuously monitor resources and the environment of our planet. The GEO science observatory would be capable of simultaneous full-spectrum observations at all wavelengths from 10^5 Hz (radio) to gamma rays. Celestial observations would benefit from long exposure times of a given source, permitting smaller instruments and continuous monitoring of variable and transient sources. Other advanced GEO missions include public service and commercial functions such as hazardous waste management, environmental modification programmes, rubbish management and tourism.

Man's presence will be required at GEO to provide space operations services to satellites as well as to large, long-life platforms and antennae. The appropriate mix of Man, remote control and automation will have been determined during the development of techniques in LEO but it is expected that GEO will introduce additional research and development requirements for communications and service operations. Since GEO operations will become increasingly complex and since they are sensitive to transportation costs, this human involvement will tend to grow from intermittent to permanent.

Human GEO habitation will likely be required beyond Year 2000. While not a necessary part of a subsequent lunar transportation system, such a manned GEO Space Station, perhaps preceded by a temporarily mannable 'shack' (*circa* 2004), would probably be also highly beneficial to a subsequent lunar programme concerned with generating lunar material resources of value such as oxygen in gaseous and liquid form. Because of its high orbital energy, a GEO facility will become an important transportation node for missions to and from cislunar and heliocentric space; non-terrestrial resources such as liquid oxygen could be an advantage.

In addition to GEO, a number of other peculiar orbits in cislunar space are promising for the post-Space Station mission goals assumed above (Table 3). They include the family of pseudo-geosynchronous orbits (for high-inclination Earth coverage), long-lifetime orbits for waste storage, high-sunlit orbits outside the Earth's shadow, and orbits passing through various portions of the plasma sphere. A typical cislunar science project could be an extra-long baseline interferometer with radio telescopes 30-100 m in diameter stationed at the Earth-Moon or Earth-Sun Lagrange points.

Part 2 of this article will consider lunar, Mars and other programmes beyond Year 2000.

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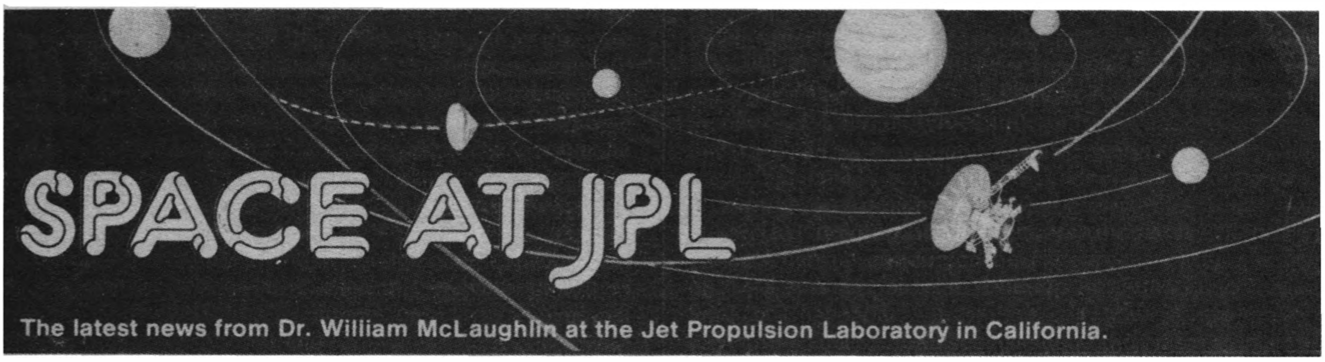


IR PROCESSING AND ANALYSIS

As reported in the April 1985 issue, the catalogue of almost 250,000 infrared sources discovered in 1983 by the Infrared Astronomical Satellite (IRAS) has been issued. The potential amount of astronomical information hidden in the data sent back by IRAS during its 300 days in orbit is so large that the Infrared Processing and Analysis Center (IPAC) has been set up by NASA as the succesor to the IRAS project.

Caltech, the parent body of JPL, will be physically and organisationally the home for IPAC. A new building is being constructed on the Pasadena campus to house IPAC and will be ready early next year for occupancy. In the meantime, IPAC is housed in offices in downtown Pasadena, where project manager Gael Squibb outlined plans for the infrared centre for *Spaceflight.*

A basic task of IPAC will be to reprocess all of the data in order to increase the sensitivity of the all-sky survey; sources from three to five times fainter than the dimmest in the present catalogue will be extracted. A second task will be to calibrate the data for the purpose of removing the effect of the zodiacal light. The zodiacal light arises from particles in interplanetary space and contributes an unwanted background glow. Since 'the zody' varies with the observing angle from the Sun and since IRAS generally observed each part of the sky at several different times of the year (and hence at several different Sun angles), the removal of the zody from each of these observations is important in order to be able to compare them properly. A third task of considerable interest will be the construction of 5 x 5° sky plates to display the whole infrared sky in a set of visual products. These will compare in some respects with the famous plates comprising the Palomar/National Geographic survey of the sky at visual wavelengths - a survey done in the 1950's and in continuous use since then.

The IPAC project is funded to the end of fiscal year 1989 (October 1989). In addition to the systematic processing of the IRAS data during this time, a General Investigator programme will be supported. Each year NASA will publish an Announcement of Opportunity and, after a selection process, successful applicants will be able to visit the Pasadena centre to pursue their individual researches, aided by the resident staff in accessing the data base. Squibb anticipates that a typical investigator might spend one or two weeks at IPAC, perhaps twice during a year.

The Chief Scientist of IPAC is Dr. B. Thomas Soifer of Caltech, who was active during the IRAS mission as a member of the international science team. His duties relate primarily to people and product interfaces with the astronomical community. Dr. Charles Beichman, also of Caltech and an integral part of IRAS, is the Project Scientist who will concentrate upon development of new capabilities for the project.

Last December a final IRAS social event took place at JPL with old friends from three countries (The Netherlands, the US and the UK) assembling to reminisce about the project on which they had worked for over eight years. Your correspondent received a thunderous ovation upon announcing his retirement as poet laureate of IRAS. In retaliation he read the following verses.

In an orbit lonely
Visited by radiation only
Rests the skeleton of IRAS
Sans programs, sans gas.

Downstairs, from the project tent
The catalog has been sent
And the folks are soon to trek
From Jetland to Caltech

No more focal plane and dewar
Instead it's map and flux contour
The hardware work has gone away
The data base is here to stay.

IRAS or IPAC; what's in a name?
No. 1 boss of the infrared game.
Galaxy, star, comet and cirrus
The infrared duo are bringing them near-us.

On a cold winter night
Orion shines more bright
Polished by many a survey pass
Done by the late, lamented, IRAS.

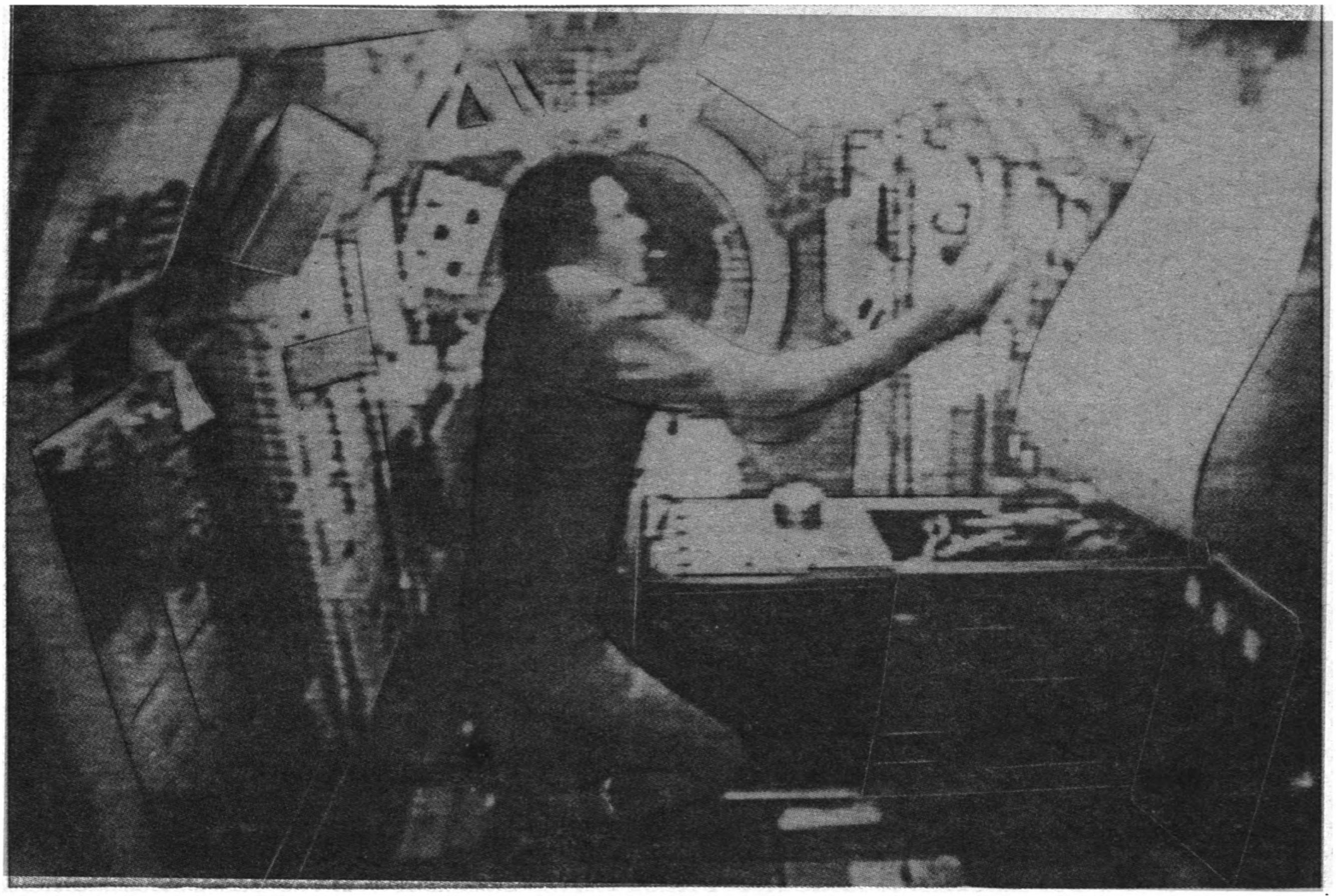
JPL SCIENTIST IN SPACE

Dr. Taylor Wang was the Laboratory's first scientist in space when he conducted an experiment in the physics of fluids aboard Spacelab 3 during the 29 April to 6 May flight of *Challenger.*

Wang was a payload specialist and the principal investigator for the Drop Dynamics Module, used to study the behaviour of drops of water, glycerine and silicone in weightlessness.

The drops were manipulated in a chamber using sound waves of various frequencies and amplitudes. The waves could also be generated in three directions such that Wang was able to rotate, oscillate and position the drops. The sound waves are sufficiently weak so that they do not interfere with the physical effects under study.

The drops, ranging from 0.3 cm to 1.5 cm in diameter, were infused with coloured particles to facilitate observations of surface phenomena and fluid flow in their interiors. Progress was not only monitored by Wang but live pictures were also transmitted to the NASA/Johnson Space Center in Houston.



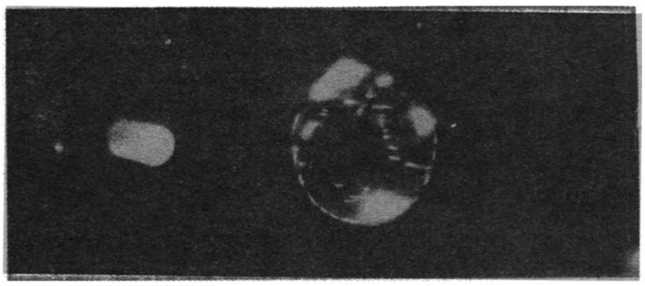
JPL scientist Dr. Taylor Wang works aboard *Challenger* to repair his Drop Dynamics Module experiment. *NASA*

The experiments had to be postponed because of equipment failure but extensive efforts by team members on Earth yielded a procedure by which Wang could identify the exact cause of failure (a power supply unit) and fix it. He bypassed the failed unit and used the remaining two power supplies to power the system.

Thus, instead of starting the scientific investigations on the second day, they began on day four, necessitating overtime on the part of Wang to complete the more than 40 hours of experimentation.

The information gained from experiments with fluids in a zero-gravity environment has scientific and industrial applications. In astronomy, certain features of the processes of star formation and rotation resemble fluid activity. The connection between this branch of astrophysics and fluid mechanics was made long ago and illustrious mathematicians such as Poincaré and Liapounov have contributed to the theory of figures of celestial bodies with very little empirical available to support them. In meteorology, raindrop formation in the upper atmosphere is in some ways a parallel activity with respect to the DDM experiments. Materials processing in space may involve the manufacture of fluoride glass for lasers. When made on Earth such glass contains imperfections arising from the crucible in which it is built. A second industrial application involves the possible manufacture of low-density aluminium in an orbital setting.

A 2 cm plastic sphere hovers in the Drop Dynamics Module aboard *Challenger*. It was used to test and calibrate the acoustic control mechanism of Dr. Taylor Wang's experiment. *NASA*



Upon his return to JPL, Wang received a warm welcome and well-deserved congratulations for a difficult job accomplished successfully. The attendant ceremony included the Laboratory Director, Dr. Lew Allen. The DDM is scheduled to fly next on the Shuttle in NASA's International Microgravity Laboratory in 1987.

PLUTO AND CHARON

In the dark, outer reaches of the Solar System, the satellite Charon orbits Pluto approximately every 6.4 days. Pluto was discovered in 1930 by Clyde Tombaugh as the culmination of Percival Lowell's programme to discover a trans-Neptunian planet. Charon was discovered in 1978 by James Christy but the discovery has not yet been officially recognised by the International Astronomical Union owing to the great uncertainty in the orbital parameters of the satellite.

However, it is known that the orbital plane of Charon is highly inclined with respect to the ecliptic. Hence, twice in every orbit of Pluto about the Sun, every 124 years since the orbital period of Pluto is 248 years, there will be a span (5.7 years) when Charon passes alternately in front of and behind Pluto as seen from Earth. Astronomers had been uncertain as to when this period of eclipses would begin and had been watching for it over the last few years.

The first observational indication of this anticipated

event was obtained on 16 January by JPL astronomers Edward Tedesco and Bonnie Buratti using the 150 cm telescope at Mount Palomar. The eclipses were detected by the slight effect they produced on the amount of observed light from the Pluto-Charon system.

Confirmation of the initiation of the mutual eclipse period was secured by Richard Binzel on 17 February with McDonald Observatory's 91 cm reflector in Texas and David Tholen with the 224 cm reflector located on Mauna Kea in Hawaii.

The importance of the eclipses is twofold. First, they will allow an accurate determination of the orbital parameters of Charon and the diameters of both bodies. Second, careful study of the light curves should reveal details about the surface properties of both bodies, particularly of Pluto. Charon will be acting as an occulting probe as it passes over the surface of Pluto, allowing deductions concerning variations in brightness on the planetary surface.

The information on the constitution of Pluto and its companion is made more valuable by the fact that it is the only planet in the Solar System that has not been either investigated by spacecraft or scheduled for such an investigation.

SPHERES OF INFLUENCE

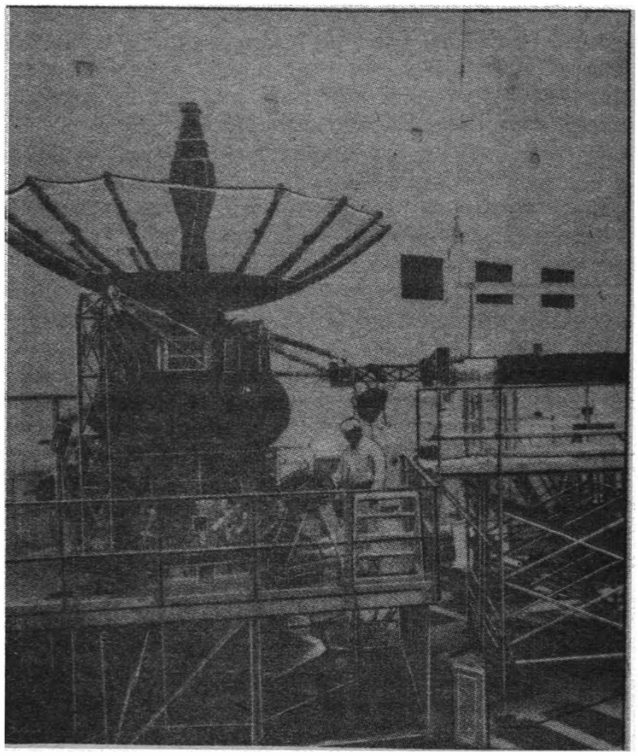
In the nineteenth century, 'spheres of influence' was commonly employed to denote a region controlled by a great power but not actually a political part of it. The same phrase is used in astronomy and astrodynamics to describe a volume of space under the gravitational control of a celestial body.

Now, in principle, the gravitational force exerted by a planet, star or any other object extends indefinitely outward but, as in geopolitics, it must face competition.

For example, in designing lunar trajectories one can achieve a first approximation by ignoring the gravitational force of all bodies except the Earth and Moon. A further simplification results by considering only the gravitational force of the Earth upon the spacecraft as long as the vehicle lies outside the sphere of influence of the Moon. For the Earth-Moon system, this is an imaginary sphere centred at the Moon and having a radius of about one-sixth of the Earth-Moon distance. As the spacecraft enters this sphere of influence, one ignores the effect of the Earth's gravity and treats the trajectory analysis as if only the Moon existed. The virture of all these simplifications is that if only one body acts on a spacecraft, it moves in a very simple way: a conic section (hyperbola or ellipse). The approximate trajectory is therefore composed of two conics, one shaped by the Earth and one by the Moon; their conjunction, the entire Earth-to-Moon trajectory, is rather colourfully referred to as a 'patched conic' (the 'patching process' takes place at the surface of the Moon's sphere of influence).

For the rough design of interplanetary trajectories a similar process is employed but in this case the relevant bodies are the Earth, Sun and target planet. The sphere of influence of the Earth (relative to the Sun) is about a million kilometres. After leaving this region the spacecraft is then treated as if it were only under the gravitational influence of the Sun. The final leg of the trajectory begins when the craft pierces the sphere of influence of the target planet. For Jupiter this is a sphere of almost 50 million km in radius (in competition with the Sun); for Mars the sphere has a radius of somewhat more than 500,000 km.

The sphere of influence concept is also useful when we inquire into the possibilities for orbiting a very small body



Galileo, seen here in test in the Spacecraft Assembly Facility at JPL, will be decidely within Jupiter's sphere of influence. *NASA*

such as a comet. For example, the sphere of influence of Comet Wild 2, which is a candidate for rendezvous with one of JPL's proposed Mariner Mark II spacecraft, is about 40 km in radius. The exact value is unknown since it depends upon the exact mass of Wild 2. The radius also shrinks as the comet approaches the Sun since the latter body becomes more dominant during this process. Orbits outside of the sphere of influence are possible, but then solar perturbations would require more orbit maintenance from the spacecraft's engines.

The sphere of influence employed in the preceding cases is not the only one that is useful. A second concept is the 'Roche limit.' This, again, is an imaginary sphere centred on a planet and defined in such a way that any natural satellite that wanders inside this sphere (whose radius is the 'Roche limit') will soon be torn apart by the tidal forces exerted by the planet on the satellite. The analysis of this stressful type of encounter was done by Edouard Roche in 1850.

All the larger natural satellites in the Solar System orbit *outside* the Roche limit of their planetary host. The main rings of Saturn are contained entirely *within* the planet's Roche limit. Most likely they are material that, as a consequence, could never form into a satellite. A second possibility is that they are the remnants of a satellite that approached too closely to Saturn and was ripped apart.

A third type of sphere of influence has been defined by astronomers in their analysis of the motions of stars within clusters. One purpose of the analysis is to determine how long clusters last before they are disrupted by the cumulative effect of close encounters between their constituent stars. These encounters can result in a star being slung out of the cluster, never to return. Over a period of a few thousand million years, the whole cluster of stars can disappear *via* this mechanism of 'gravitational evaporation.' A simplified study of the situation is facilitated by suitably defining a sphere of influence for each star and noting how frequently a second star is likely to enter this sphere, initiating a significant gravitational interaction.

HALLEY'S COMET UPDATE

THE COMET IN *SPACEFLIGHT*

Halley's comet will be visible in our skies until next May and will then fade below naked eye visibility until increasingly larger telescopes will be needed to find it. *Spaceflight* intends to present interesting facts about the 1985-6 return of the comet until it becomes completely lost to view once more. An invitation is extended to all members to contribute suitable short items for publication.

HALLEY'S COMET EVENT

A press conference held at the Royal Society on 26 April discussed the return of Halley's comet. Four speakers, under the Chairmanship of Professor A.J. Meadows, described the event to an audience of about 100. Dr. J. Davies began by posing the question 'What is a comet?' adding that, if we knew the full answer, the meeting would have been superfluous! Aristotle's views that they were atmospheric phenomena had remained unchallenged for nearly 2,000 years until Tycho Brahe observed the comet of 1577 and proved that it was an object beyond the Moon. Nowadays, comets are believed to be objects left over from the formation of the Solar System, 4500 million years ago, and really time capsules from that period.

The coma, typically as big as the Earth, prevents us from seeing the nucleus. During the spring 1066 return the coma of Halley's comet was 100 times the size of the Earth: its tail was half as long as the distance between the Earth and the Sun. Usually, a comet develops two tails. One is yellow because it reflects the sunlight and consists mainly of dust; it is frequently curved. The second tail is longer, straighter and often bluish in colour. It is composed of ions.

Dr. David Hughes reminded the audience that Halley's comet was captured by Jupiter 170,000 years ago, thus making it a member of the inner Solar System. Its period varies between 79 and 68 years, averaging 75.6 years.

This time we will be able to see the comet over a total period of seven years. For comparison, in 1910 the total observing period was 1½ years, in 1835 it was six months and, earlier, just a few weeks. The first photograph at its previous return was taken at Heidelberg on 11 September 1909, the last on 30 May 1911 when the comet was about the distance of Jupiter.

Professor J. McDonnell and Dr. A. Johnstone then addressed themselves to some of the Giotto experiments. There were three main questions to be resolved: 1. What does the nucleus look like? 2. What is it made of? 3. How is the tail structure formed and will features of the Earth's magnetosphere be reproduced by the comet?

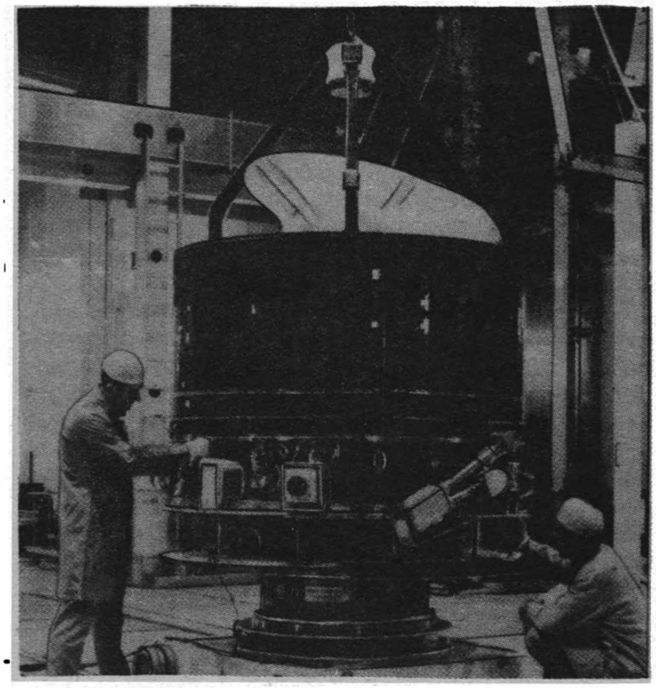
The aim of Giotto is to home in on the coma and to fly within 500 km of the nucleus on the sunward side. Final flight adjustments to achieve this would be based on photographs and results from the Soviet Vega craft. Intercept will be 13-14 March, between 11 p.m. and 3 a.m.

Halley's nucleus appears to be lemon-shaped, 10 km long and rotating. It loses about one part in a hundred thousandth of its mass every time it passes the Sun. Having gone round the Sun 500 times already, it is now a middle aged object or, in other words, when first captured by Jupiter it was twice its present size!

It doesn't seem likely that this return of Halley will be be very spectacular in British skies. If one gets away from the city lights and allow one's eyes to adapt to the dark of the countryside, it can be picked up through small telescopes and bionoculars towards the end of October 1985 though mid-November (Moon free) will bring an even better chance to see it at dusk, when it will be just south of the Pleiades.

The first naked-eye observations will probably be possible in December, again at dusk. The comet will get brighter and develop a tail in January but stay low in the Western sky and, by the end of the month, will set before

Giotto was completed and officially accepted by ESA following a two day review board meeting in May. The Agency issued a certificate of acceptance and formally took delivery at the French space agency's Intespace facility in Toulouse, where the majority of the environmental testing and payload integration took place. Giotto began the first stage of its 150 million km journey to Halley's comet at the end of April when it left Toulouse on an Air France 747 for French Guiana. Eight months later, on 14 March 1986, it will pass as close as possble to the nucleus of Halley's comet. During the critical encounter which, at best, will last four hours, data from its ten experiments will be relayed in real time back to Earth.



the sky gets dark. Towards the end of February the comet will be seen again, in the morning twilight, and with a lengthening tail. By mid-March it will appear with a long tail, in the moonless morning sky, just above the horizon.

HALLEY STAMP

The Post Office issues special pictorial stamps to mark important occasions. One of the special sets to be issued in 1986 will feature astronomy and will coincide with the perihelion of Halley's comet.

There will be four stamps in the set, which will also be sold in a presentation pack containing interesting background information.

The special stamps will be available from most Post Offices up to two weeks from their date of issue. Postcards and presentation packs will remain available for two months, subject to stocks.

They will also be on sale for 12 months by post from British Philatelic Bureau, 20 Brandon Street, Edinburgh EH3 5TT and from 64 special post office philatelic counters.

COORDINATION OF OBSERVATIONS

Astronomers have introduced many new types of instrumentation and observing techniques since Comet Halley's last return in 1910. This time coordinated observation both from ground and space should produce a major leap forward in our understanding of comets. The key word here is 'coordinated.' Best returns on the research effort are likely to come from many near-simultaneous observations spread over all the available electromagnetic spectrum. For example, ground-based observations of the cometary dust, especially in the infrared, will provide information on how its amount and distribution change with time. Detailed dust measurements made *in situ* by space probes can then be fitted into this ground-based picture. The two sets of observations together will have greater value than either done on its own.

British astronomers are particularly fortunate in having access to several large telescopes covering most regions of the spectrum. These range from the UK Infrared Telescope (UKIRT) in Hawaii, to telescopes for observation in the visible at La Palma, in the Northern hemisphere, and to the large-scale photographic capabilities of the UK Schmidt Telescope in the Southern hemisphere.

Here in the UK a Comet Halley UK Coordinating Committee (CHUKCC) has been set up by the Science and Engineering Research Council (SERC) and the Royal Astronomical Society (RAS) to coordinate the activities of professional and amateur observers. SERC has provided funding for a full-time coordinator to assist the Committee in its activities. One problem posed by the unprecedented observational effort devoted to Comet Halley is the large amount of data that will accumulate. To cope with this, CHUKCC has set up a sub-committee, Comet Halley UK Information Technology (CHUKIT), to suggest ways for storing and handling the data.

CHUKCC is linked to the international coordinating body for Comet Halley studies - the International Halley Watch (IHW). The IHW prepares and distributes information about Comet Halley aimed not only at professional and amateur astronomers but also at schools and the general public. Within the USA, IHW and NASA information is distributed *via* an electronic mail network. The UK is now connected to this system.

The IHW is providing equipment for UK meteorologists to observe the comet from St. Helena. Independently, the British Antarctic Survey will be observing the comet from their Halley base.

Although the prime target of these coordinated activities is Halley, two other comets need to be mentioned. During March 1984, the IHW held a test run for its observers on Comet Crommelin. Apart from revealing a number of deficiencies in observing and communications procedure, this produced some interesting new knowledge of comets. In September 1985, the US ICE probe (International Cometary Explorer) will encounter Comet Giacobini-Zinner. ICE has a UK experiment on board; and CHUKCC intends to mount a ground-based observing campaign before and during the encounter.

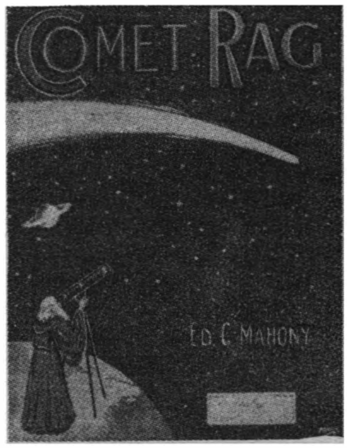
Review

Halley's Comet 1910: Fire in the Sky

J. Metz, Singing Bone Press, P.O. Box 1650, St. Louis, MO 63188, USA, 1985, 124pp, $13.95.

This is not a book on Halley's comet itself, nor even an astronomy book, but one in which the public interest shown in the last 1910 return of the comet is recreated in the form of cartoons, advertisements, postcards and the news and views of the time - all written and presented in light-hearted fashion.

In 1910 the comet was visible to the naked eye and through binoculars in April-June. On the night of 18 May, when the Earth was to pass through the comet's tail, large number of peoples waited and watched with mingled fear and awe. Actually, the appearance of Halley's comet had been outclassed by the Great Daylight Comet which appeared in the January of that year. Only four or five comets appear each century which are bright enough to be seen during the day so this one, which appeared in Capricornus and stood forth brighter than Venus - and with an impressive tail - caused many people to confuse it with Halley!



Halley's comet was the inspiration behind a whole variety of products during the 1910 return, including this 'Comet Rag' music.

The most absorbing part of the Halley apparition, in retrospect, is the large numbers of stories woven into its reappearance e.g. associating it with a large outbreak of sunspots and a spectacular meteor display, though prime among these, certainly, must have been the Earth's journey through the comet's tail. This prompted the French astronomer, Flammarian, to predict that enough toxic gases might be present to bring animal life on Earth to an end!

Advertisers, cartoonists, poets and composers alike made good use of Halley's comet to promote their wares, postcard manufacturers being particularly in the fore. Much of the humour depicted seems outdated in today's sophisticated age but a number of the illustrations retain their attractiveness. Particularly interesting were the several music compositions, one being a Comet Rag written specially for the occasion.

Stories similar to the sort described are already beginning to emerge in the press in connection with the 1986-7 return, though not on so large a scale. One example is, a Mr. Mackins, in the *Daily Mail* of 31 October 1984 who - referring to Halley's comet - warned 'Records show the comet to be a portent of warm weather. In the year before it reappeared in 1835, Britain had the second highest temperatures ever known.'

HALLEY'S COMET AND BABYLON

Dr. R. Stephenson and Kevin Yau

The appearance of Halley's comet in 164 BC was previously thought to have passed unrecorded. Recent work, however, shows that this was not so.

Introduction

When we produced our translation [1] of Far Eastern records of Halley's comet from earliest times (240 BC) to AD 1378 we held the opinion that the Chinese chronicles would contain the earliest reliable records of the comet. We have since made a discovery that proves this is not the case.

Evidence from Babylon

Late Babylonian texts in the British Museum contain numerous fragments of astronomical diaries dug up at the site about a century ago. These total about 1200 fragments, half of which can be dated either from the historical information they contain or by astronomical calculation based on the lunar and planetary observations recorded.

In a joint paper with H. Hunger of University of Vienna [2]. We have shown that, among the 10 or so Babylonian references to comets, there are three descriptions of Halley's comet as observed in the years 164 BC and 87 BC. The earlier apparition is particularly well recorded on two separate tablets, the details of which overlap. These Babylonian observations represent the only known sighting of Halley's comet at this return from any part of the world. In addition, this may be confidently considered as the earliest fully reliable sighting of the comet. The 87 BC record is rather brief but, besides giving a few observational details, gives an exact date and the first known estimate of the length of the tail (some 10°).

The records may be translated as follows:

164 BC

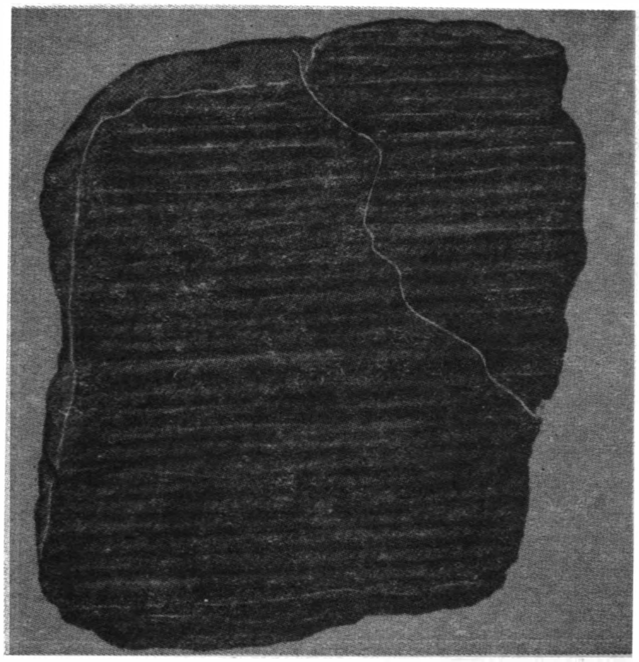
(a) 'The comet which previously had appeared in the east in the path of Anu in the area of Pleiades and Taurus, to the west... and passed along in the path of Ea.'

(b) '... (in the path) of Ea in the region of Sagittarius, 1 cubit in front of Jupiter, 3 cubits high toward the north...'

87 BC

'On the 13th (of the lunar month), the interval between moonrise and sunset was 8° measured; first part of the night, a comet... which in month IV day beyond day, one cubit... between north and west its tail 4 cubits...'

None of the texts contain a surviving reference to the date but all contain enough lunar and planetary observations to enable in each case a unique date to be established as the result of computation. In addition, some of the details on the texts (a) and (b) of 164 BC are duplicated, proving that they share a common date. The first pair of observations can thus be shown to come from lunar month VIII of the year 148 of the Seleucid Calendar (164 BC Oct 21 to Nov 19). The remaining observation has a date month V of the year SE 225 (87 BC Aug 12 to Sep 9), but with a reference to regular motion of the comet in the previous month (Jul 14 to Aug 11).



A portion of a Babylonian text provides data related to Halley's comet in 164 BC. *British Museum*

The details in 164 BC are sufficient to demonstrate that Halley's comet is indeed referred to. Merely by varying the perihelion by a few days, it is possible to represent accurately the observed motion including the fairly close approach to Jupiter (1 cubit was equivalent to about 2.5° in angular measure). The calculated date of perihelion passage is within about one week of Nov 16 in 164 BC.

The rather less specific observation in 87 BC, which we interpreted to relate to last visibility of the comet on Aug 24, allows the date of perihelion in that year to be calculated as within about 10 days of Aug 5.

Various numerical integrations of the motion of the comet have appeared in recent years but only those of Yeomans and Kiang [3] - which take account of a number of accurate Chinese observations of the comet - represent the observations satisfactorily and in both cases agreement with those translations is excellent.

In our view these can be confidently used in studying the long-term motion of the comet.

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HALLEY'S COMET

Halley's comet reached aphelion in 1948: since then it has been steadily accelerating towards the Sun and is predicted to reach perihelion (its closest approach to the Sun) on 9 February 1986.

The 1986 return is forecast to be unspectacular and may even go unseen by most people. One reason is that its position at perihelion is on the opposite side of the Sun, as seen from the Earth, so it will be lost in the solar glare until about a fortnight after perhelion passage.

Later in the spring, when it comes from behind the Sun, its apparent motion will carry it rapidly towards the south, to the disappointment of those in the northern hemisphere.

The comet has a retrograde motion around the Sun with an inclination of 162° to the ecliptic.

Subsequent returns will not be until 2061, then 2136 and then 2211 AD.

SPACELAB 3 EARLY RESULTS

Following the successful conclusion of Spacelab 3 on 6 May, many of the experiment teams have made a preliminary analysis of the results.

Materials Science

A mercury iodide crystal about the size of a sugar cube was successfully grown from a seed crystal in the Vapor Crystal Growth System over a period of 104 hours. Analysis will determine its quality and properties as an X-ray and gamma ray detector for applications in scientific research, medicine and industry.

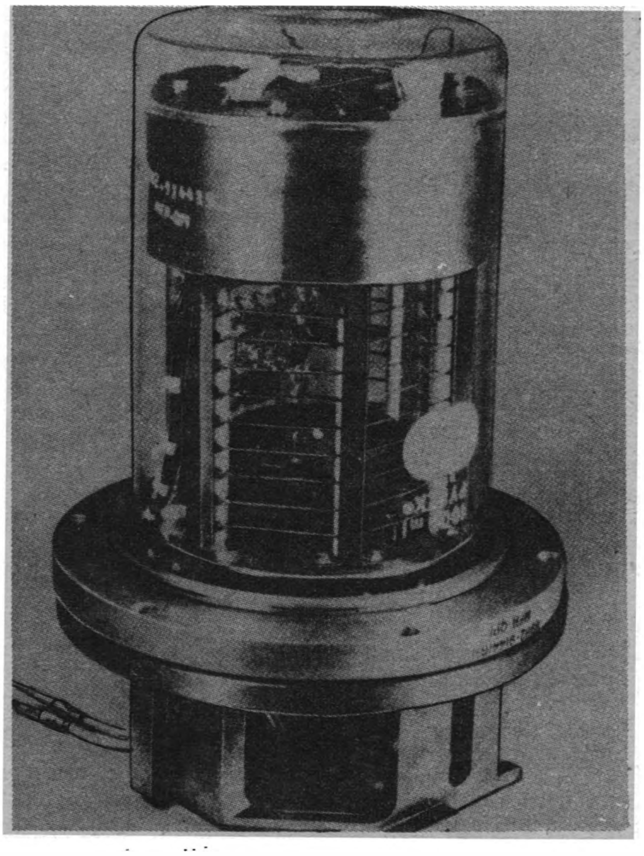
Two triglycine sulphate crystals were grown in the Fluid Experiment System, the first to use the fluid transport technique in space. The two crystals are undergoing thorough analysis to determine their quality and properties as sensitive infrared detectors.

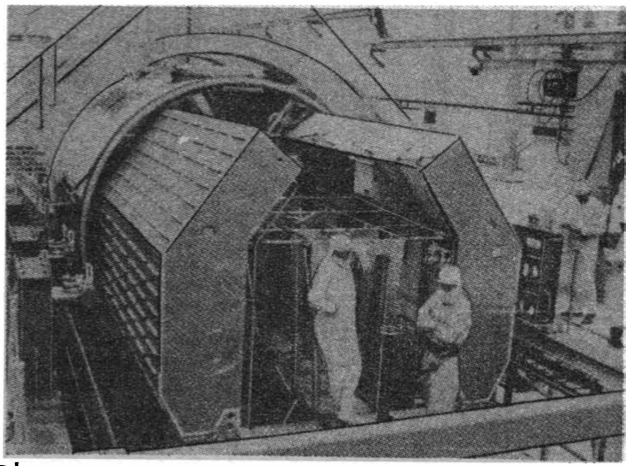
Fluid Mechanics

Two fluid mechanics experiments were completed successfully. The Geophysical Fluid Flow Cell experiment ran for 102 hours to provide information on convective flows in rotating spherical bodies, simulating planetary atmospheres. The films of one of the Jovian simulations indicated the formation of a 'Red Spot' similar to that present on Jupiter.

The Drop Dynamics Module, after a successful repair by payload specialist Dr. Taylor Wang, provided the first data on the behaviour of a free-floating fluid in microgravity. Wang and his colleagues working in the Payload Operations Control Center were able to perform their experiments nearly as they would in an Earth-laboratory - changing the procedures and adjusting the equipment in response to the results observed first hand. This opportunity to 'fine tune' the experiment in progress is one of Spacelab's most useful qualities.

The vapour crystal growth furnace on ground test. Material from the mercuric iodide source (at left) migrates down to the seed crystal at the bottom, visible as a white spot. The furnace is only 17 cm high.





The Spacelab 3 experiment racks are slid into the pressurised shell in the Operations and Checkout Building at the Cape. *NASA*

Atmospheric and Astronomical Observations

Three atmospheric and astronomical observations were completed.

The Atmospheric Trace Molecules Spectroscopy Experiment operated for 50 hours, providing 19 sequences of more than 150 independent atmospheric spectra. Each spectra contains more than 100,000 individual spectrally resolved measurements which will be used to analyse the Earth's atmospheric composition chemically and physically for the stratosphere and mesosphere between 10 and 150 km. This information will provide an extremely detailed measurement of the minor and trace components of the atmosphere, crucial to understanding the evolution and the Earth's climate. In addition, the experiment also provided the first high resolution infrared spectrum of the Sun.

Eighteen Auroral Imaging Experiment observations were carried out with aurorae clearly visible. This marked the first time since the early 1970's that an aurora experiment had flown on a manned vehicle and was the first American experiment to pass through three separate aurora, possible because of the high-inclination orbit of the Shuttle. Video tape images from the experiment will be processed to yield three-dimensional images of auroral structure and motion.

The Studies of the Ionization of Solar and Galactic Cosmic Ray Heavy Nuclei experiment, also called Ions, was mounted outside the pressurised module and successfully collected data on high energy particles streaming towards Earth from the Sun and from more distant sources in the galaxy. Tracks in the detector will be analysed to identify the trace of cosmic rays to determine their specific ionization state, intensity, energy spectrum, arrival time and direction.

Life Sciences

Six life sciences experiments were completed successfully. The new Research Animal Holding Facilities were demonstrated; the two squirrel monkeys and 24 rats adjusted well to space flight and demonstrated their suitability for research in orbit. One primate apparently developed symptoms of space sickness but recovered in a manner similar to humans.

SATELLITE SAILING

By Jerome Pearson

In 1987, NASA will launch the first tethered satellite, a geophysical probe to take measurements in the upper atmosphere. The satellite will be lowered almost 100 km below the Shuttle, becoming the first application of long tethers in space. Long tethers will be used later for orbital transfer and re-entry, lunar satellite launches and many other devices. One of the most exciting is in 'satellite sailing': hanging a lifting body into the upper atmosphere to change the orbit plane of the Shuttle. The lifting body could also function as a hypersonic 'wind tunnel without walls.'

Introduction

The use of long tethers in space is a technical subject that it is rapidly coming of age. Over the past quarter of a century, two separate traditions have matured, each with its own particular view of elongated space structures. On the one hand, engineers have devised tethers to tie astronauts to their spacecraft during extravehicular activity and to tie two orbiting spacecraft together for artificial gravity. These proposals were initially very limited in scope and effect. In contrast, others have held a more speculative outlook, imagining enormously long tethers attached to the Moon, spacecraft, asteroids and the Earth to perform unprecedented feats. For more than 15 years there seemed to be no common ground or contact between these two groups; each continued its own researches, oblivious of the other.

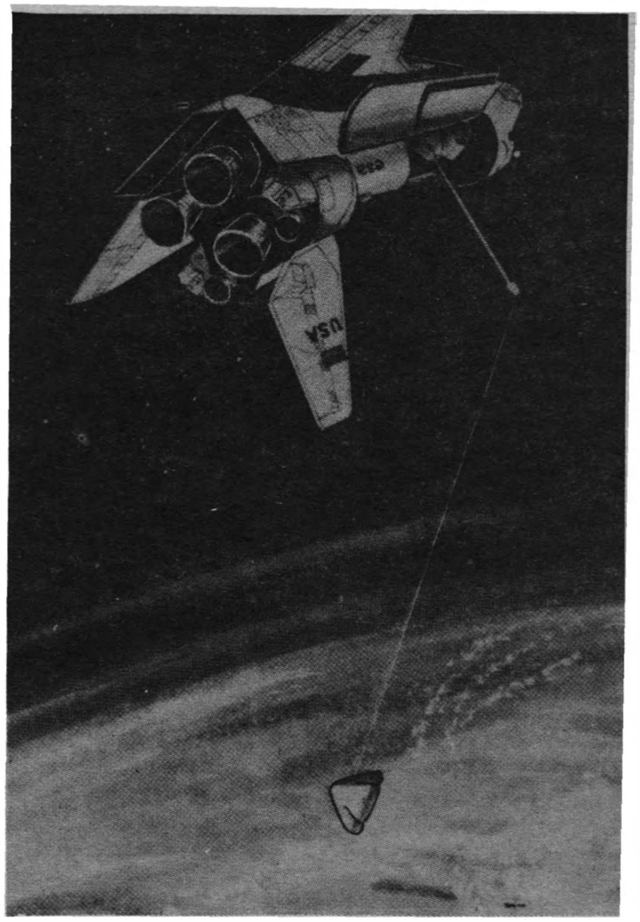
Distant Visions and Near-Term Realities

The visionaries came first. In the 1960's and 70's, several conceived the possibility of dropping a line from a geostationary satellite to the ground, forming a 'space elevator' or 'orbital tower' and using it to climb into orbit without rockets. Unfortunately, these grandiose schemes required materials far beyond existing engineering capabilities. They also considered extremely long tethers to attach spacecraft to the Moon, for the orbital capture of one spacecraft by another, for orbit-changing manoeuvres akin to Jupiter flybys, and for catching and throwing satellites into Earth orbit. Gradually, the newer concepts were refined to require less material strength and to come closer to practicality.

During the 1960's, engineers of the Gemini and Apollo space programmes found many new and practical uses for short tethers. They suggested tethering an astronaut to his capsule during a spacewalk, connecting two satellites during rendezvous and tethering a constellation of spacecraft together in orbit.

Others extended these ideas to more ambitious schemes. Perhaps the best known is the 'skyhook' scheme of the late Guiseppe Colombo of the University of Padua. He first proposed the lowering of a sub-satellite from the Shuttle into the upper atmosphere to make geophysical measurements at altitudes that were too high for balloons and too low for satellites. Professor Colombo died in 1984 but his ideas will become a reality in 1987 when the Shuttle unreels the first tethered satellite.

Meanwhile, visionaries were having their ideas accepted by wider groups. The Society's own Arthur Clarke presented a popular paper at the 1979 International Astronautical Federation conference that summarised the grand schemes for the space elevator [1], and several other



A lifting body is unreeled from the Shuttle cargo bay. *US Air Force*

papers were published about orbital rings and other configurations. The resulting intense interest in tethers led Ivan Bekey of NASA Headquarters to convene the 'Applications of Tethers in Space Workshop,' held in Williamsburg, Virginia in June 1983. The result has been a flowering of proposals for the use of tethers that are at once very practical and highly spectacular.

The Tether Workshop

The Workshop brought together ideas for near-term and far-term applications. Guiseppe Colombo was there, along with many others who had worked on tether concepts for a decade or more. The conference proceedings [2] contain a fascinating listing of possibilities for the rest of this century. The conferees formed six panels to discuss tether applications in Science, Electrodynamics, Transportation, Artificial Gravity, Satellite Constellations, and Technology and Test. Tethers were suggested for creating artificial gravity in elongated structures, for creating large constellations of tethered spacecraft flying in formation and for generating power. For this last application, a long conducting tether could generate power as it cut lines of force in the Earth's magnetic field, at the expense of creating additional drag on the Shuttle. Among the more exciting possibilities is that of 'satellite sailing.' This idea is based on lowering an aerodynamic shape into the upper atmosphere from the Shuttle and using the resulting aerodynamic forces to change the orbit of the Shuttle [3]. The device is called a sail because it would act like a sail on a sailing craft; it would change the craft's direction by the force of the wind.

Satellite Orbit Plane Changing

The Shuttle can launch or retrieve multiple satellites on

a single flight if they are in a single orbital inclination. In order to service satellites in orbits with different inclinations, the Shuttle would need to change its orbital plane. However, changing the orbital plane of a satellite by more than a few degrees requires a large amount of energy. The case of moving a satellite from an equatorial orbit to polar orbit is an extreme example. It is actually easier to land the spacecraft and launch it again into the polar orbit than to perform the change in space! For this reason, no satellite has changed its plane by more than a very small amount.

There were proposals during the US Air Force Dyna-Soar project in the early 1960's to have the 'Aerospaceplane' dip into the atmosphere, bank in a broad turn and then re-boost into orbit in a new plane. These ideas were shelved when the programme was cancelled in December 1963. The Shuttle has aerodyanmic lift and could conceivably be used for this manoeuvre. However, the requirement to dip into the atmosphere and to re-boost makes it an expensive proposition.

An easier way is to extend a lifting body on an extremely long tether from the Shuttle. Because of the gravity gradient force, such a configuration of two masses on a long string would align itself along the local vertical. This is caused by the differential gravity and angular inertia of the two bodies at different distances from the centre of the planet. If the lifting body were extended far enough downward into the upper atmosphere, it would create aerodynamic lift that could be oriented horizontally to change the orbital plane.

Satellite Sailing

A spacecraft changing its orbital plane in this manner would extend the sail first to one side of its orbital path and then to the other as it moved about the Earth, like a sailboat 'tacking' against the wind. The alternating force would precess the orbital plane, just as a rotating bicycle wheel is turned out of its plane when a torque is applied to it.

To change the plane of the Shuttle is no easy task, however, because the orbiter vehicle weighs more than 70 tonnes and even in the weightlessness of orbit its inertia is intact. A sail large enough to move the Shuttle around would need to have an area almost as large as the Shuttle itself, and it would be necessary to lower it 80-100 km on a very strong tether. If such a large sail could be built, using an erectable or inflatable structure, the Shuttle orbital plane could be changed at the rate of several degrees per day.

Satellite sailing would be the leisurely way to change orbits, compared with the rapid, critical dip into the atmosphere required by the synergetic manoeuvre. With such a satellite sail, the Shuttle could be launched into one orbital inclination and perform a satellite launch or service. The crew could then lower the sail to change orbital planes. This procedure would require several days. First, the sail would be ejected from the cargo bay to a distance of several hundred metres, until it developed a small tension in the tether. The tether would then be unreeled, slowly at first, then faster as the sail descended farther and the tension increased. The sail would reach its full distance of 80 to 100 km after 8-12 hours. It could then be commanded to swing from one side of the orbital plane to the other by radio commands to its flaps, the way a model aircraft is controlled by wire. The Shuttle orbit change would take place over a period of several days while internal experiments, such as those on Spacelab, were being performed. Once the Shuttle reached its new orbital plane it could launch, retrieve or service another satellite in a radically different orbit. Finally, the Shuttle crew could slowly reel the sail back into the cargo bay, being careful not to excite large oscillations and prepare for landing.

The drag of the tether is a difficult problem for the satellite sail. The tether must have a large enough diameter to withstand the aerodynamic and gravity forces on the sail and it must also have a high heat resistance because of atmospheric friction. Even though the tether could be tapered from a large diameter at the Shuttle to a small diameter at the sail, it might still be necessary to streamline the tether, like the streamlined wires used to brace biplane wings. The problem of tether drag means that larger sails would be more efficient. Large sails to change the plane of the Shuttle orbit would have less tether drag than small sails to change the plane of satellites launched from the Shuttle.

Wind Tunnel Without Walls

There is another interesting application of the tether lifting body that is not critically dependent on tether drag. This is the idea of 'trolling' a flight vehicle through the upper atmosphere to observe its flight characteristics. With a Space Shuttle in a normal orbit and a 100 km-long tether, such a test object would experience wind speeds of 25 times the speed of sound (Mach 25) at an altitude of about 100 km. This is an extremely interesting flight region difficult to simulate in a wind tunnel.

If the Shuttle could be fitted with the tether device planned for the 1987 tethered subsatellite test and have a lifting body rather than the satellite attached, it could become, in effect, a Mach 25 hypersonic wind tunnel. Experiments could be performed on the problems of optimising the shape of re-entry vehicles for maximum cross-range and controllability during descent. It would also be possible to communicate with a satellite during the blackout period of re-entry by using the tether as a signal carrier.

The hypersonic 'wind tunnel without walls' could also be used as a testbed for trying out new materials for heat shields, new aerodynamic shapes and new cooling concepts for trans-atmospheric vehicles. The test bodies could be reeled out on the tether, tested at leisure, then reeled back into the Shuttle cargo bay for return to Earth, analysis of the data and examination of the structure for damage. It is even possible that such lifting bodies might be tethered from satellites in orbit about other planets, such as Mars, Venus and Jupiter, in order to study their atmospheres or to modify the satellite orbits.

Current NASA Plans

There are many other concepts for long tethers that may find useful applications in the next few years. The NASA budget for Fiscal Year 1986 includes several million dollars for further tether research in addition to the tethered subsatellite launch. Among the first tether applications will be the tethered wind-tunnel and the electrodynamic tether to generate spacecraft power.

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SHUTTLE 51C MISSION REPORT

By John A. Pfannerstill

The 51C Shuttle mission in January 1985 was the first fully devoted to a military payload. The launch saw the first use of the Inertial Upper Stage aboard the Shuttle since its failure in 1983, its performance proving that it is now fully operational.

Introduction

Mission 51C was the first flight of the winged spaceplane to be entirely dedicated to the Department of Defense. In the future, such missions will become common, with the military being NASA's main customer on about 20% of the next 70 flights.

For the first time in its history, NASA was compelled to impose restrictions on press coverage. Inquiring reporters were not provided with the usual reams of fact sheets, timelines and Press Kits. Requests for interviews were turned down and there were no press conferences. In addition, the Defense Department ordered NASA to impose a near-total news blackout while the flight was underway. No air-to-ground voice or video was to be released and there would be no NASA mission commentary. Even the scheduled time of launch and the planned mission duration were kept secret. NASA justified its new procedures by stating that it always tried to comply with the needs and requests of its various Shuttle customers.

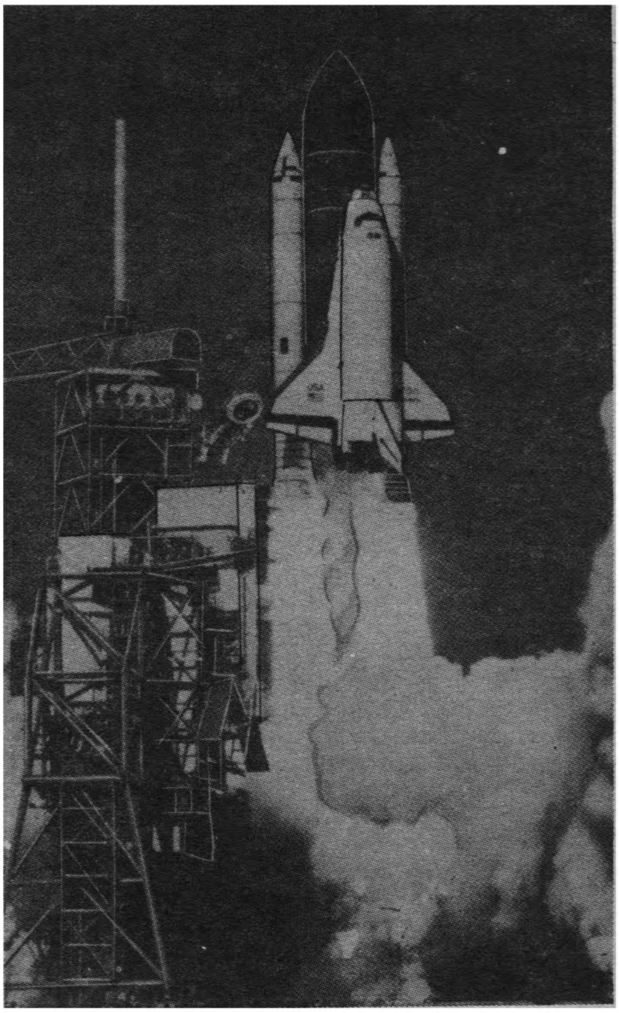
There was some limited information that NASA was allowed to release in advance. Reporters were told that the *Discovery* would lift off from the Kennedy Space Center on 23 January 1985 sometime between 18:15 and 21:15 GMT (all times are GMT). Aboard would be NASA astronauts Navy Commodore Thomas K. Mattingly (Commander), USAF Lt. Col. Loren J. Shriver (Pilot), USAF Major Ellison S. Onizuka (Mission Specialist) and Marine Lt. Col. James F. Buchli (Mission Specialist). Also included was the first to fly of a group of military astronauts, USAF Major Gary E. Payton, who would serve as the lone Payload Specialist.

Newsmen would receive written mission status bulletins every eight hours. These would say only whether the flight was going well or not; no specifics would be released. As the flight neared its conclusion, the exact time of the planned landing would be disclosed in one of these status reports some 16 hours before touchdown.

The payload itself was another matter. The Defense Department would say nothing about it except that it would make use of an Inertial Upper Stage (IUS), the first time it had been used on the Shuttle since its STS-6 failure in April 1983. Since so many non-military projects depended on the IUS, DoD agreed to release basic information on its performance.

Despite the best efforts of DoD and NASA, details about the satellite did leak out to newsmen. Bearing the classified code name 'Aquacade,' it was reported to be a large 'Signals Intelligence' (Sigint) spacecraft destined for operation in geosynchronous orbit over the western Soviet Union. Such satellites have been in use by the US and the Soviets for many years. In simple terms, they listen in on radio transmissions and then, either storing or re-transmitting the data in real time, send the information back to their home countries.

Although not widely publicised, US Sigint satellites are thought to have been involved in revealing the Soviet Union's only known manned launch aborts (Soyuz 18 in 1975 and Soyuz T-10 in 1983) by eavesdropping on the cosmonauts' voice communications.

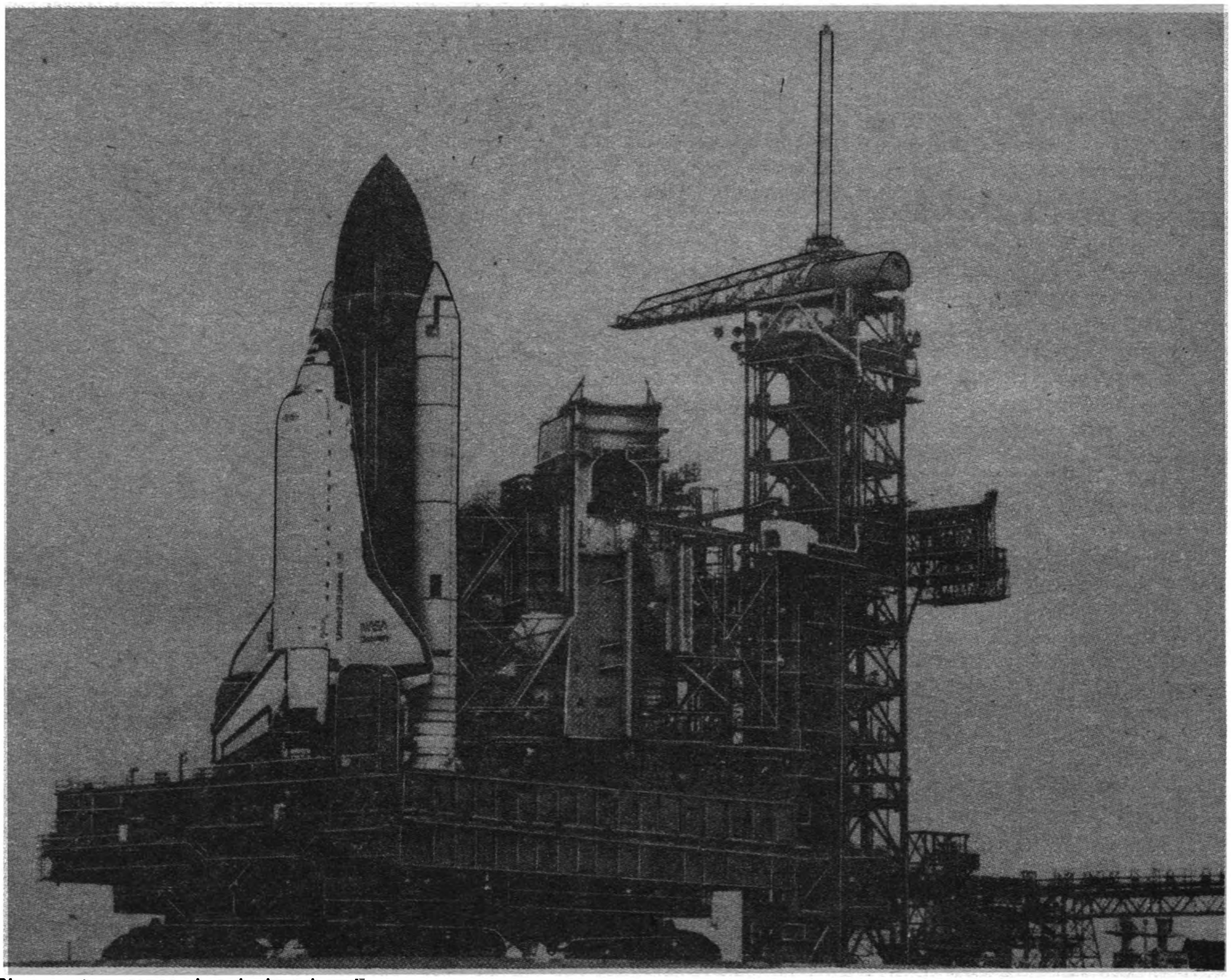


Discovery's third launch. NASA

The 51C Aquacade was said to be of a brand-new state-of-the-art design that was 'light years ahead' of those flown earlier. When deployed in orbit to its full 30.5 m size, the satellite would reportedly be able to pick up radio, microwave, telephone, teletype and satellite communications through its two large deployable dish antennae. It was also said to have the capability to move around in its geosynchronous orbit to make it harder to locate.

Troubles with the IUS following STS-6 delayed the launch of Aquacade for more than a year. At first, the satellite was set for launch with the Mattingly crew on STS-10 in December 1983, but IUS delays pushed it back to July 1984 on 41E, before more IUS testing woes forced a further postponement to 51C. At that point, the Orbiter stepped in to cause more re-scheduling.

The 51C launch was originally scheduled for 8 December 1984 aboard the *Challenger,* just three weeks after the landing of *Discovery* from 51A's Westar/Palapa retrieval flight. But, as technicians were examining *Challenger* in early November, they discovered that a vulcanising material coating its metal skin had softened, affecting the bonding of some 2800 tiles. Engineers determined that it would be necessary to remove the tiles, replace the vulcaniser and then reapply the tiles. All of this was expected to take a considerable time and, in the final analysis, NASA decided that it would be quicker to turn



Discovery is transported to the launch pad.

The 51C crew. From left: Gary Payton, Loren Shriver, Tom Mattingly, James Buchli and Elison Onizuka. Mattingly, a veteran of Apollo 16 and STS-4, was the only experienced astronaut aboard. *NASA*

Discovery around after 51A, aiming for a mid-January launch.

Mission Day 1: 24 January 1985

The third launch of *Discovery* was delayed by 24 hours because of the unusually cold weather that hit the southeastern US in the days immediately before the scheduled 23 January liftoff. A blast of Arctic air sent the mercury plummeting below freezing (highly unusual for Florida at any time of the year) and NASA officials were concerned that ice would build up on the External Tank. As a result, late on 22 January, NASA announced a one-day postponement. This was the first time in the US space programme that a manned mission had been delayed due to cold weather.

On 24 January, however, conditions were almost perfect, with near-normal temperatures and a clear blue sky. It was some of the best weather yet for a Shuttle launch. There was no KSC Public Affairs commentary and the countdown clocks around the Press Site were blank.

Beginning at around 14:00, sharp-eyed observers armed with telescopes were able to spot wisps of vapour around the External Tank, indicating that the fuelling process was underway. Then, at about 16:30, the silver 'Astrovan,' presumably carrying the five crewmen, was spotted heading out to the launch site. Many interpreted this as a sign that the launch would come in about three hours.

In an arrangement agreed with DoD finalised just days before the launch, NASA was permitted to provide its normal countdown commentary as soon as *Discovery* came out of its final built-in hold at the T-9 minute mark. At 19:41 the countdown clocks came to life and KSC Public Affairs Director Hugh Harris calmly started giving a rundown of the terminal count events.

The countdown proceeded smoothly and *Discovery* vaulted into the sky at exactly 19:50:00. Visibility was excellent and spectators were able to follow the Shuttle easily with the naked eye even well after the Solid Rocket Boosters had separated. It appeared to be heading due east, which indicated an orbital inclination of about 28.5°.

For those listening on radio, Johnson Space Center PAO Terry White provided narration of the ascent events but the actual voices of the astronauts were not broadcast. His steady stream of data continued through to main engine cut off, ET separation and the first Orbital Maneuvering System (OMS-1) insertion burn. Immediately after the OMS-2 burn, however, the commentary ended.

Mission Day 2: 25 January 1985

Following NASA's confirmation that *Discovery* was safely in orbit, no information was provided until the first mission status bulletin was released early on 25 January.

The first one-sentence statement said, in its entirety, that: '*Discovery*, its crew and all elements of the Space Transportation System are performing satisfactorily.' One report issued later in the day did elaborate somewhat with 'the Mission Control team continues to snack on macadamia nuts furnished by mission specialist Ellison Onizuka, a native of Kona, Hawaii, and the team has passed along their thanks to him.'

Most news reports were consistent in their assertion that the satellite was deployed on Day 2, possibly at around 12:00.

The Orbiter was also carrying a civilian experiment developed by Australian scientists to study human blood. The object was to obtain data on how zero-gravity affects the aggregation of red blood cells, particularly in diseased individuals. This information was expected to be helpful in the development of new drugs. The equipment was

Gary Payton, the first of the non-NASA military astronauts to fly.

contained in two cylindrical packages in *Discovery's* mid-deck and was completely automatic. The crew had only to switch it on and once its 8-10 hour cycle was completed, it would shut off automatically.

Mission Day 3: 26 January 1985

Again, little information was released. The standard, short bulletins kept coming every eight hours, announcing that Mattingly, Shriver, Onizuka, Buchli, Payton and *Discovery* were all continuing to 'perform satisfactorily.' There was no word yet on landing plans but most sources were predicting that reentry would occur on 28 or 29 January.

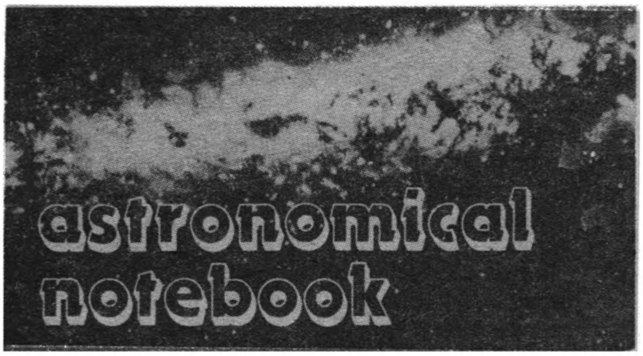
Mission Day 4: 27 January 1985

Early on 27 January, NASA announced that touchdown at KSC would take place later in the day at 21:23. Reportedly, the landing had been originally planned for 28 January but the threat of bad weather at the Florida landing site prompted JSC flight controllers to advance it 24 hours. Weather predictions for 27 January called for scattered clouds with 11 km visibility, which would be acceptable conditions.

Accompanying the landing announcement was a brief statement that the IUS had 'successfully met its mission objectives.' As expected, there was no elaboration nor was there anything in the bulletin to provide a clue as to exactly when the satellite was set free.

As the scheduled time for landing approached, NASA resumed its usual Public Affairs commentary but, as during launch, the actual voices of the astronauts were scrambled electronically and thus were not available for broadcast.

Discovery streaked across the southeastern US as it decelerated from near-Mach 25 orbital velocity down through the speed of sound. As a measure of how routine such landings had become, for the first time none of the major US television networks covered it live. Mattingly brought *Discovery* down to a perfect touchdown on Runway 15 at exactly 21:23:23. After a minute, it rolled to a stop, its 47-orbit mission complete after 3 d 1 h 33 m and 23 s.



By Prof. John Griffith
of Lakehead University,
Ontario, Canada.

ATMOSPHERE OF A SUPERGIANT

Astronomers have to work with the radiation from objects and have no opportunity to physically alter or interact with the objects under observation. Ocassionally they are fortunate in that events outside their control give information that would otherwise be unobtainable. In the case of a particular supergiant, μ Sagittarii, it has been found that the star is part of a binary system with shallow eclipses providing soundings of the atmosphere of the supergiant as the light from its companion passes through the atmosphere.

HD 166937 is a bright (3.9 mag) supergiant, otherwise known as μ Sagittarii. Ronald S. Polidan of the Lunar and Planetary Laboratory, University of Arizona and Mirek J. Plavec of the University of California, writing in 'A hot companion to mu Sagitarii: an opportunity to sound the atmosphere of a B8 1a Supergiant.' *Astronomical Journal,* **89,** 1721-1717, 1984, point out that the radial-velocity curve of the B8 1a component of μ Sagittarii indicates its binary nature. Satellite observations (Copernicus, IUE and Voyager) have identified the companion as a hotter star (probably B1.5V). The eclipse of the hotter companion appears to be total, lasting longer than 15 days.

The orbital cycle has period around 180 days. The authors advocate a systematic observing programme using both the IUE and the Voyager instrumentation. Preceding the primary bodily eclipse there will be an atmospheric eclipse with the hotter companion shining through progressively optically thicker outer atmospheric layers of the B8 supergiant, providing our first opportunity to probe the outer atmosphere of a star of early spectral type.

COOL WHITE DWARFS?

White dwarfs have no nuclear energy source. When they have contracted as far as possible, with the gravitational force balanced by pressure due to electron degeneracy, they are expected to cool, eventually becoming 'black' dwarfs with very low temperatures. However, no faint white dwarfs have been discovered, nor have invisible components of binary systems with masses of the order of one solar mass been found. K. Freese of the University of Chicago proposes in her paper 'Do monopoles keep white dwarfs hot?,' *Astrophysical Journal,* **286,** 216-220, 1986, that white dwarfs are powered by the magnetic monopoles predicted by grand unified theories. Such monopoles, on capture by a white dwarf, would catalyse nuclear decay, with the energy being thermalised and adding to the radiation from the surface. Alternative explanations include such an age for galaxies that white dwarfs have not had time to cool, or longer cooling times brought about by phsyical separation of carbon and oxygen as the dwarf crystallises (Mochkoistch, R., 1983, *Asrtronomy and Astrophysics,* **122,** 212). K. Freese utilises a model white dwarf of 0.6 solar masses, radius 9×10^8 cm, average density 4×10^5 g/cm^3.

Once captured, monopoles inside a white dwarf tend to sink towards the centre, within less than an hour. Using previously calculated values for the energy generated leads to eventual domination of the luminosity output by monopole energy release. Monopoles would have a negligible effect on the overall structure of the white dwarf. 'The catalysis process could be preventing white dwarfs from cooling down into a stellar graveyard by keeping them hot.'

GALAXIES AND QUASARS

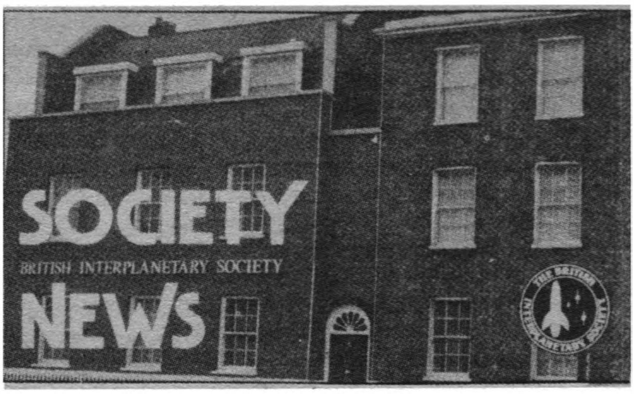
As we see further into space we are detecting galaxies at earlier stages in their development. At a distance of ten million light years we see the galaxy as it was ten million years ago. With the expectation that the Edwin P. Hubble Space Telescope will finally enable us to detect the epoch of galaxy formation, L.W. Hastmann, J.P. Huchra and M.J. Geller of the Harvard-Smithsonian Center for Astrophysics have been investigating the best method for detecting primeval galaxies. Writing in 'How to find galaxies at high redshift,' (*Astrophysical Journal,* **287,** 487-491, 1984) they predict that primeval galaxies will have more in common with metal-poor, relatively dust-free, extragalactic HII regions and clumpy irregular galaxies than with dusty, metal-rich star burst galaxies. The best hope for discoverying primeval galaxies with high redshift (produced by the Doppler shift from Hubble's raw relating speed of recession to distance) is to observe the redshifted O and B stellar continue past 1 m in the infrared.

The properties of galaxies underlying quasars are discussed by M.A. Malkan of Steward Observatory in 'The underlying galaxies of quasars. II. Imaging of a radio-loud sample,' *Astrophysical Journal,* **287,** 555-565, 1984. The aim was to study the optical properties of host galaxies and the dependence of these properties on the optical and radio luminosity of the active quasar nucleus. The Palomar 1.5 m telescope was used to investigate 26 quasars and it was found that the galaxy morphology was correlated with the presence of radio emission.

Radio-quiet quasar galaxies have the colour, size, surface brightness and scale length of normal early-to-intermediate type spiral galaxies. Most of the radio-loud quasars appear to reside in moderate to bright elliptical galaxies.

K.D. Borne of the Palomar Observatory has been using computer simulations to study the interraction of binary galaxies. His results are given in 'Interacting binary galaxies. I. A numerical model and preliminary results,' *Astrophysical Journal,* **287,** 503,-522, 1984. It is considered that the gravitational interaction between galaxies has played an important role in the evolution of the Universe. Cluster galaxy distribution and structure indicate that the history has been dominated by interactive gravitational dynamics.

In binary galaxy systems, the interaction leads to a redistribution of matter, energy and momentum. A close encounter often leads to merger of the two galaxies (from the inelastic nature of the tidal interaction).



SHUTTLE BRIEFING

The Executive Secretary represented the Society at a Shuttle briefing presented by a team from Rockwell International at Les Ambassedeurs Club in London on 29 May. Dr. Rocco Petrone (President Space Transportation Systems Division and former NASA Associate Administrator) began by describing the versatility of the Shuttle system.

The programme had been authorised in 1972 with the first craft due for *delivery ten years later*. Actually it flew in 1981. *Discovery* was delivered in 1983 and the roll-out of *Atlantis* took place earlier this year.

Experience with Shuttle flights 1-17 were not only now giving improved turnaround times but showed excellent systems performance in orbit. The thermal protective system (the tiles), designed to stand an external temperature of 2,500°F, yet keep the internal Shuttle temperature to no more than 200°F, had performed their task satisfactorily. Shuttle flights had delivered 18 satellites, deployed one in orbit, retrieved one, retrieved and repaired one and returned two to Earth. Future plans included the launch of the Shuttle from Vandenberg into a near-polar orbit, with an early task of refuelling a Landsat satellite. The August mission to rescue the malfunctioning Leasat was very demanding, replacing an equipment panel and then moving away quickly to allow the satellite to fire its main engine.

Future possibilities are concerned with the fabrication of large structures in space, especially the Space Station. Spacelab, in one sense, was a forerunner of the Station for it was really a laboratory moved from Earth to 300 km high and placed in a completely new environment. Designated areas of interest to Spacelab are materials, life sciences, fluid mechanics, Earth observation and astronomical observation though, if one knew exactly what achievements lay in store, it would no longer be an experimental laboratory!

Spacelab 1 flew in November/December 1983, Spacelab 3 in April 1985 and Spacelab 2 in July. Spacelab D-1 is due later this year, financed entirely by Germany and concerned, particularly, with materials processing experiments.

Future Shuttle missions include deep space launchings. Ulysses, a Solar Polar mission, is due for launch on 15 May 1986. This would involve a flight to Jupiter and then a swing-shot back to pass over the North Pole of the Sun some four years after launch. Galileo is designed to orbit Jupiter for about two years and to send a probe into its upper atmosphere. Launch is expected on 21 May 1986.

Mr. Seymour Rubinstein (President, Space Station Systems Division) added that Space Station studies had actually begun in 1970. The main aims of the project would be:

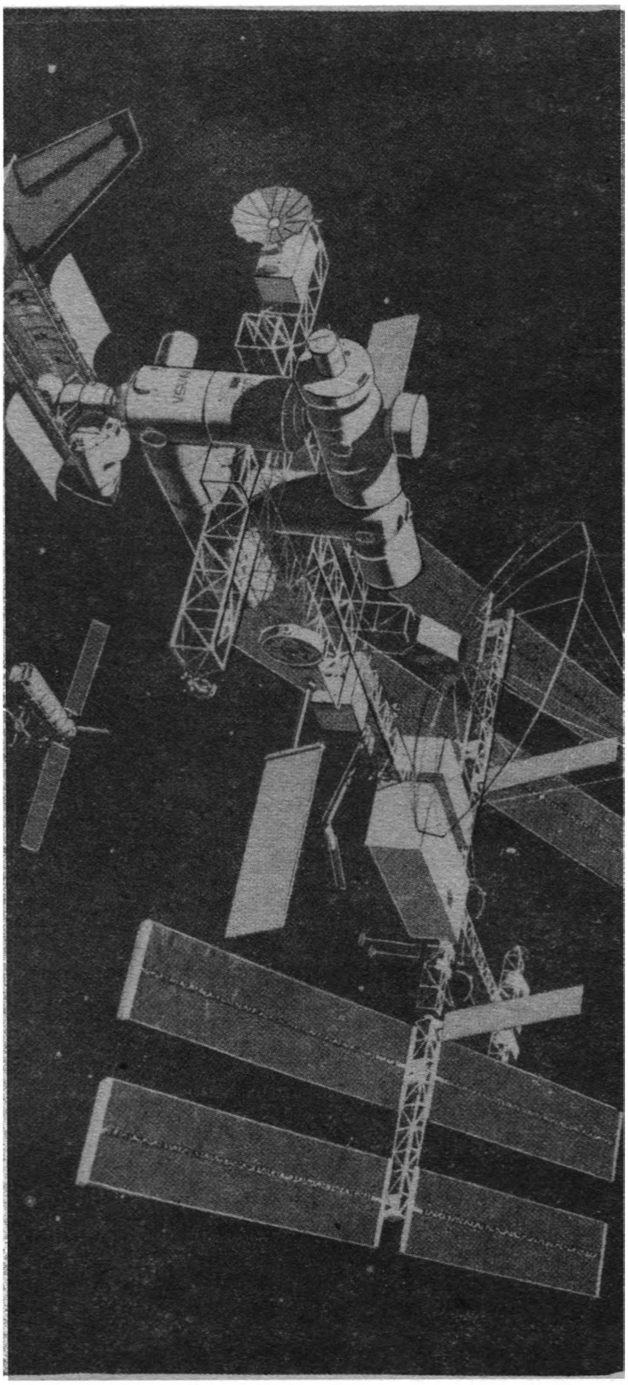
1. To stimulate advanced technology generally.
2. To develop a commercial interest in space.
3. To stimulate interest in science and engineering education.

It was item (3) which made the project significantly different from other earlier major space programmes. As currently planned, the initial dimensions of the station were 294 ft wide and 396 ft long. There would be a crew of six-eight. Its main modules would be:

1. Crew living quarters
2. Materials processing laboratory
3. Life sciences laboratory
4. Logistics modules and storage

Programme definition studies are due to be be completed around September 1986, the configuration depending on

A Rockwell concept for the US Space Station.



the power system (designed to provide 75 kW). Two options are open:

1. Photovoltaic. This is expensive and required some 20,000 sq.ft of solar panels.
2. Solar dynamic. This concentrates the Sun's energy by mirrors which are then used to drive turbine/generators and so produce power. This would only require one third of the area for (1).

The Solar dynamic system is the one that looks more cost effective. It has been proven terrestrially, but has not yet been space tested. Energy requirements for expanded space stations beyond the year 2000 would probably be met by nuclear power.

In subsequent conversations Dr. Petrone ranged over a wide field, from individuals to matters of distant policy. Would there, for example, be a case for more than one Space Station e.g. polar orbiting, or placed in deeper space? Would there be unmanned, fully manned or occasionally manned stations? Would some emerge in lunar orbit, the libration positions in the Earth-Moon system and will they become characteristic of future manned planetary missions - perhaps involving sending a complete station on a long duration (measured by years) mission?

He provided plenty of reminiscences about earlier pseudo barriers to space progress. There was the zero-g barrier, the thermal barrier, the speed of sound barrier and the re-entry barrier. We now have what seems to be a time-barrier i.e. the one that restricts progress towards the stars. Meanwhile, there were always many willing to say "Let's rest at this point for a while" - still disregarding the warning on this very point (on the Elysian fields) given in John Buchan's "Pilgrims Progress" centuries ago.

Plenty of reminiscences of Wernher von Braun emerged. For example, while V-2s were being shipped out of Nordhausen for transit to White Sands, Wernher was also en route to American under the alias of a Swiss ball-bearing manufacturer. As ill-luck would have it, a travelling companion turned out to be a bicycle manufacturer who wanted to place orders!

When men first set foot on the Moon Wernher was asked, "What does this event mean to you?" He provided a typical response:

"We have taken a step to Man's immortality."

SOCIETY PUBLICITY

Recent press coverage included an excellent article on the Society in the *Daily Telegraph* of 5 January 1985 by Bob Conquest, in which he not only included our address but had quite a number of nice things to say about us. This was echoed by Douglas Arnold writing in the *Mensa* journal, also for January 1985 and who also not only included membership details in a letter in that magazine but our address as well. Unfortunately, an article on the Society, with coloured illustrations, appearing in the *Telegraph Sunday Magazine* 25 November last was greeted with mixed feelings. True, it included a photograph of the Council, and of our HQ, but the text was something of a mish-mash. Equally mixed were feelings about the long interview with our Executive Secretary in the *South London Press* of 3 April. Ostensibly about his new book but most was about the Society, the book gaining only an incidental mention. Howard Ilett, on the other hand, continued to fly the flag in an article in the *Portsmouth Evening News* of 22 January last which described the Society's work in a highly polished manner.

We came out somewhat better in periodicals. *The London Cigarette Card News* of February 1985 contained an article on 'Space Cards' based on the *Space Education* text on the subject while, farther afield, Lester Winick in an article in *Linn's Stamp News* of 20 November 1984, described not only Zucker's pre-war rocket flights but mentioned the Society too. Also in America, *Space Calendar* for April 1985 reprinted the list of important events in the return of Halley's comet from *Spaceflight* adding our address too.

A review of *Spaceflight* appeared in *Tahdet Ja Avaruus* (Finland) last August, while *Teknikmagasinet* for June-July 1984 (Sweden) ran a piece about Project Daedalus and other Society work. Project Daedalus also featured in a magazine published in Greece in August-September last, whose title is even harder to pronounce.

On the radio, our President, A.T. Lawton, featured in a BBC overseas service newscast in April, picked up by BBC 4 and rebroadcast in 'The World Tonight' and subsequently syndicated to other radio stations worldwide.

Bookwise, Tim Furniss included our name and address in his new book *Our Future in Space*, with a repeat performance in a companion volume *The Story of the Space Shuttle*. Robin Kerrod did the same in his new book, *The Challenge of Space*.

We also continued to support exhibits with a number of displays of Society literature though, with demand growing and a depleting supply, problems are emerging for the future.

Finally, Project Daedalus surfaced again, not in the media this time but as the topic selected for an entry in a Speakers Competition!

FROM THE SECRETARY'S DESK

Dr. Owen Garriott

It was fascinating to talk to Owen Garriott, sitting alongside as one of the Guests at the Goddard Memorial Dinner in Washington last May. Owen, who was a mission specialist on the STS-9/Spacelab 1 mission in November/December 1983, was due to fly again later this year with his close neighbour, Claude Nicollier, a Fellow of the Society. Claude was originally an ESA payload specialist but is now a NASA mission specialist. Owing to the cancellation of the November flight, both will now be re-allocated to later missions.

Owen made a particular point of asking me to convey his good wishes to all the Members of our Society. With little to hand in the way of writing materials, we made the best use we could of one of his visiting cards. His message is reproduced here.

Looking to the future — international cooperation/ participation in Space Station —
Owen Garriott

Halley's Comet?

Reference to the recently-identified 164 BC sighting of Halley's comet in the Babylonian tablets mentioned in *Spaceflight* earlier on reminds me of an unexplained mystery of my own. During the 1930's when pursuing this subject, my attention was drawn to a newly-published work on Babylonian excavations that mentioned a stele describing the appearance of a paricularly bright comet during the reign of Nebuchadnezzar. Unfortunately, the war intervened so I was never able to go back to examine the reference in detail nor have I found anyone, since, able to throw any light upon it.

I now see that there were four rulers with this name, reigning from 1124 to about 500 BC so, even if the reference is not to an even earlier appearance of Halley's comet, it is certainly of interest.

It seems likely that the ruler was Nebuchadnezzar II (605-562 BC) who expressed his power in a good deal of monumental architecture but if anyone can pin this down further, I'd be pleased to know.

Franks for the Memory

I was saddened the other day to learn that a very fine collection of First Day Covers relating to British Rocket Mail Experiments, and similar ventures, was disposed of without reference to the Society simply because the owner was unaware of our interest, and even more so to reflect that this was not the first time that such a thing has happened.

It is perfectly understandable that those who gain such pleasure in building up sets of First-Day Covers are not inclined to part with them lightly but, on the other hand, a times does arise, sooner or later, when the question of disposal crops up.

In every case it is hoped that the interest of the Society is kept in mind but, where such owners are oblivious of our activities, we would ask any members on the spot to put them right.

I also see that my text on Charles Golightly (*Spaceflight* March 1985 p.142) has been badly mauled. I originally included a note to the effect that a cachet, in the form of a caricature, appeared on an early rocket flight cover. This was deleted on the grounds that it was not so and that the cachet had actually been produced for a pre-war stamp exhibition.

Happily, I can now prove my point for a recent visit to the National Air and Space Museum in Washington not only unearthed material on Golightly but also brought to light covers showing the cachet prepared by the Indian Air Mail Society around 1936-7. The envelopes for the Golightly cachets were rocket-flown as a fund-raising exercise.

I was amused to notice some of the 1935 covers prepared by the Cleveland Rocket Society and intended to be rocket-flown for the same reason.

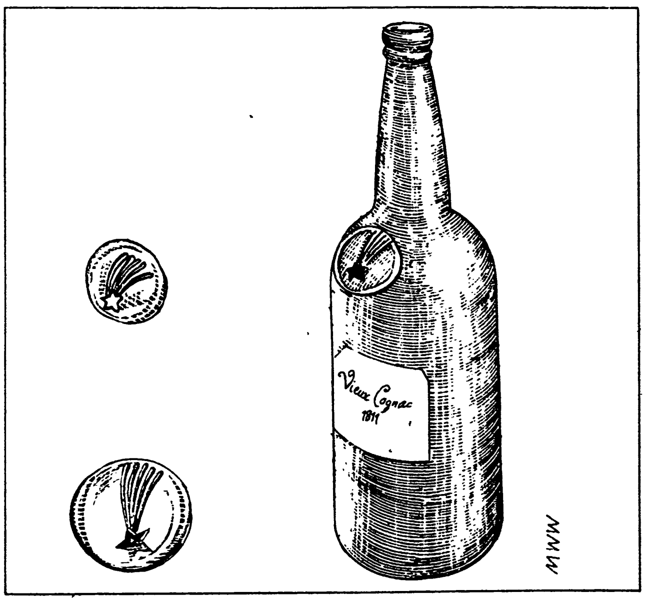
They never left the ground. The group must, however, have included an aspiring financier, for a nice touch of authenticity had been added by singeing one side of each envelope to give the impression they had had a fiery time aloft!

Comet Wine Bottles

Looking at a collection of old wine bottles the other day reminded me that I still want a comet wine bottle for the Society, though I will probably have to await the return of Halley's comet before this is achieved.

During the 19th century many wine bottles were specially embossed, following the appearance of a particularly bright comet, in the belief that the comet had enhanced the quality of the wine. These bottles, some of which are still around, are most attractive, but none has yet come my way.

Should any member of the Society, particularly those resident in continental Europe, ever see one, please do get it for us.



SOLAR OPTICAL TELESCOPE

By John Bird

Man has always been curious about the Sun, yet, in spite of recent advances, many mysteries remain - some of which will be answered by NASA's Solar Optical Telescope (SOT).

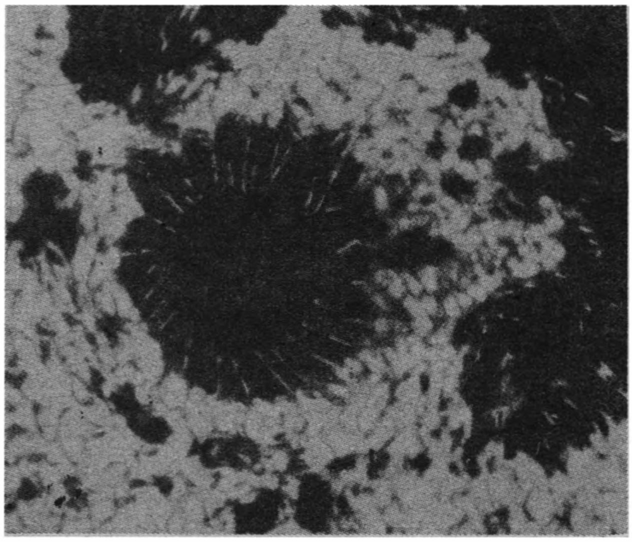
Introduction

As described to *Spaceflight* by Dr. Ernest Hildner, chief of the Solar Physics branch at NASA's Marshall Space Flight Center, SOT is the next logical step in solar physics. Although NASA has been planning SOT for over four years, funds have not yet been approved so the project is on 'hold.' The intention is that it will be flown periodically in the Space Shuttle on Spacelab "dedicated" missions in which the entire flight is given over to one discipline. Eventually, it is hoped that the telescope will be incorporated into the Space Station scheme.

The schedule for the first flight has already been planned, with delivery to Kennedy Space Center in Florida expected in October 1988, followed by launch in October 1989. Maximum flight duration will be 14 days, with an orbit of 450 km altitude at 57° inclination; orientation will be optimised for solar observations throughout the entire flight. Two Spacelab pallets, an Instrument Pointing System and an 'igloo' will be carried to produce a payload weight of 10,370 kg. On pallet-only configurations, the igloo is used to provide electrical power and cooling for the pallets and associated experimental hardware. It is pressurised and temperature controlled.

Scientific Objectives

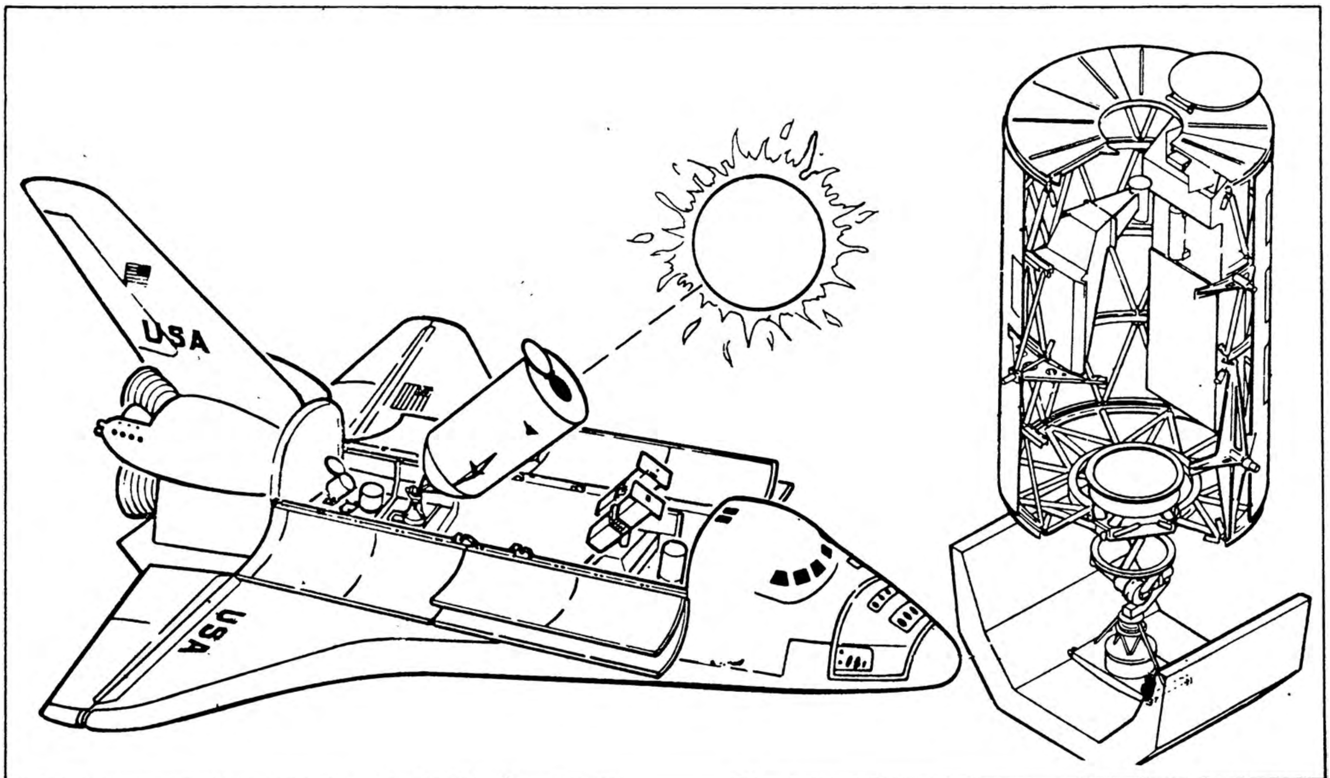
The investigations are based on the high resolution available with SOT: the 0.1 arc-seconds (or 72 km on the

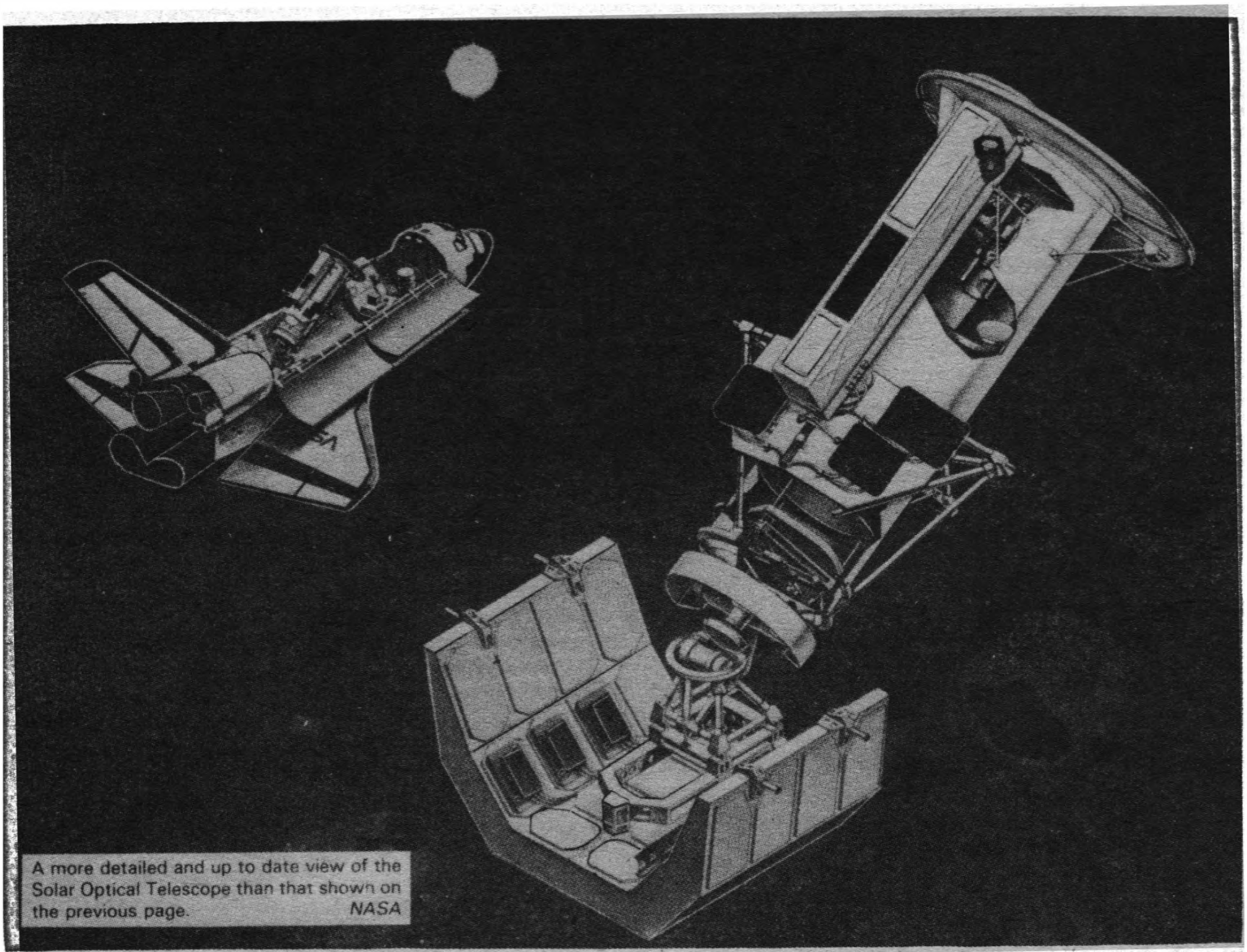


The Solar Optical Telescope will be able to study the fine structure of the Sun. *NASA*

Sun as viewed from Earth) will be much better than that available from the best ground-based telescopes - where atmospheric interference is a degrading factor. This capability is enhanced by a wide wavelength band (from ultraviolet to infrared), allowing studies from the visible surface (photosphere) through to the corona. It will investigate the diverse phenomena that reveal the Sun's complex and violent disturbances including, for example, the huge flaming arcs (prominences) suspended far above the main body by magnetic fields. Also to be analysed are the sudden solar flares which reach temperatures of 10^7°C. The fine granular structure of the Sun's surface will be clearly visible. For the first time we will be able to study its motions to help us understand heat transfer processes in the photosphere.

Scientists have posed many questions about sunspots that finally may be answered with SOT. Some are associated with the characteristic 'magnetohydrodynamic waves' and strong magnetic fields in the spots.





A more detailed and up to date view of the Solar Optical Telescope than that shown on the previous page. *NASA*

The Hardware

The basic support structure is a 3.8 m diameter, 7.3 m long cylinder housing an Articulated Primary Mirror assembly. The 1.5 m aperture, f/3.6 Gregorian optical system will be actively aligned and focused by the APM. For accurate pointing, the telescope housing will be structurally separated from the Instrument Pointing System.

Thermal control is a major influence: a normal instrument operating temperature of just under 20°C will be maintained using passive and active systems. For example, there will be insulation on the inside and appropriate coatings on the outside for passive control. Active systems will include heaters. Internal surfaces not exposed to sunlight will be blacked to maximise radiative heat transfer; sunlit surfaces will be covered with silvered teflon sheets.

Maintaining the primary mirror at the required temperature means that heat rejection from the back because of absorption on the front will be necessary. A thermal gradient will exist in the mirror and in order to prevent distortions it will have to be uniform and perpendicular to the surface. The mirror edges will thus be reflective or insulated.

The telescope will employ a variety of imaging and spectroscopic focal plane instruments. A baseline set for the first flight includes a Tunable Filter System, an Ultraviolet/Visible Spectrograph and a Photometric Filtergraph. On later flights, these would make up the Gregorian Focal-Plane Facility (GFPG).

The Tunable Filter System will produce images with high spectral and spatial resolution in the visible range. Spectral resolution will be 0.004 to 0.0125 nm (1 nm = 10^{-9} m) and spatial resolution will be 0.1 arc-seconds in a field of view of 100 arc-seconds. The Ultraviolet/Visible Spectrograph will have interchangable gratings to produce spectra detected by eight charge-coupled device arrays. For the wavelength range 100 to 200 nm (ultraviolet) the resolution will be 0.0003 nm, while at 1000 nm (near infrared), the resolution will be 0.0016 nm.

The Photometric Filtergraph is simply a camera with filters that correspond to the strongest solar spectral lines. The spectral range of this system is 160 to 600 nm (ultraviolet to red). Some 40,000 frames will be taken during the first mission.

Crew involvement will be required for the first flight of SOT. Payload Specialists will control the telescope from the Payload Specialist Station at the rear of the Shuttle Orbiter through the Spacelab Data-Display Unit and keyboard. They will aim and focus it as well as plan the observing sequences with ground-based investigators at the Payload Operations Control Center. Along with Mission Specialist astronauts, they will monitor and transmit engineering test and housekeeping data.

Orbiter attitude will likely be gravity-gradient stabilised, with the tail pointing to Earth, to optimise stability *and* provide a good view of the Sun.

SOT will evolve into a general purpose observation facility flying periodically. Later missions might require EVAs for film retrieval and operation. It is possible that this could be fully controlled from Earth although this will be limited by the amount of data that can be transmitted. Eventually, SOT will be the centrepiece of the Advanced Solar Observatory (including other solar instruments such as the Pinhole/Occulter Facility) as part of the Space Station system, possibly attached to the Space Station itself.

BOOK NOTICES

Rings: Discoveries from Galileo to Voyager
J. Elliot and R. Kerr, The MIT Press, 126 Buckingham Palace Road, London SW1 9SD, 1985, 209pp, £19.50.

The story of all three known sets of planetary rings (Jupiter, Saturn and Uranus), emphasises the enormous range of new discoveries which have taken place over the last five years. Saturn, for example, can now be seen to possess thousands of dazzling and mysterious ringlets within its three traditionally accepted rings.

One of the authors, James Elliot, played a leading role in discovering the Uranian rings in 1977, the first planetary ring system to be found since Galileo first observed those of Saturn in 1610.

The book opens with a first-person account of the discovery of the rings of Uranus, including excerpts from the tape running as the crew aboard the airborne observatory realised that they were seeing something never seen before. Subsequent chapters provide a brief history of our understanding of rings up to the early part of this century and the development of the occulation method of exploring relatively small-scale planetary phenomena. It continues by tackling the theoretical question of how narrow ring systems exist in stable form, before introducing the discovery of the Jupiter ring system and providing a look to the future, including the Voyager 2 encounter with Uranus in 1986.

The two new unsuspected ring systems surrounding Jupier and Uranus provide a series of perplexing new problems. What could put a kink in a ring or make it elliptical? How can a ring be only a millionth the age of the rest of the Solar System? Explanations have been slow in coming.

International Space Programmes and Policies
Ed. N. Jasentuliyana and R. Chipman, North-Holland Publishing Co., P.O. Box 1991, 1000 BZ Amsterdam, The Netherlands, 1984, 552pp, $65.

This book contains the proceedings of the second UN Conference on the Exploration and Peaceful Uses of Outer Space (Unispace) held in Vienna in 1982. It provides an overview of national and international programmes and policies, including the report of the Unispace conference which was unanimously adopted by the 94 participating countries. It also contains excerpts from national position papers - ranging from Argentina to Yugoslavia and including such places as Malawi, Ecuador and the Upper Volta, but not the UK - submitted by 61 countries, including all with substantial space programmes.

Although the national papers showed much divergence of views on controversial political and legal questions, there was much general agreement so the organisers were well pleased with the result.

The book, therefore, represents a unique compilation of official government policies, plans and programmes - covering a wide range of countries, both developed and developing, and including much information not previously made generally available.

Jane's Spaceflight Directory
R. Turnill, Jane's, 238 City Road, London EC1V 2PU, 1984, 311pp, £30.

This is a revised and updated version of *The Observer's Spaceflight Directory* (1978) which, itself, combined, expanded and updated the material in the two Observer's books on manned and unmanned space flight.

Like most Jane's books, the arrangement is alphabetical by country, but unlike them the arrangement is then by project rather than by company - obviously sensible when a particular programme may involve numerous major contractors. Another departure from normal Jane's practice is that while, for example, *All the World's Aircraft* gives only 'planes known to be in production or under development, this book lists all known space projects, including those like Vostok and Apollo, that have ended.

No praise can be too great for the enormous amount of vastly detailed information given - not only in the main sections on national and international programmes but in space logs listing all manned flights and major unmanned ones, in sections on launchers, military space, the Solar System, space centres, space travellers and contractors, and in an addenda bringing the information up to mid-1984.

This may prove to be a major reference source from now on.

Interacting Binary Stars
Eds. J.E. Prings & R.A. Wade, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, 1985, 220pp, £25.

This introductory account provides the physical background needed to understand interacting binary stars *viz*, star systems where the members are sufficiently close to each other to cause interactions. Particular matters discussed include e.g. why the size of the star is limited by the presence of a close companion and how such limitation leads to matter being transferred from one star to another, together with the role of binary stars in the context of stellar evolution.

Interest in binary stars, particularly in the later stages of their evolution, increased enormously in the early 1970's with the discovery that the brightest X-ray emitting stars in the galaxy are members of binary systems. Also of interest are contact binaries i.e. stars which consist of two stellar cores surrounded by a common envelope. There is also the area of cataclysmic variable stars. These are short-period binary systems with typical periods of only a few hours. They all seem to be relatively faint objects and it was only the advent of freely available large telescopes and photon-counting detectors recently which has now made them more accessible for study.

Most of the above notes are not reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

DO YOU REMEMBER?

25 Years Ago...
19 August 1960. A USAF C-119 cargo plane succeeds in snatching the descending re-entry capsule from Discovery 14 in the first successful mid-air recovery.

20 Years Ago...
29 August 1965. Astronauts Cooper and Conrad complete the eight day Gemini 5 flight, which saw the first use of electric fuel cells.

15 Years Ago...
17 August 1970. Venera 7 is launched on a 120-day flight to Venus. An entry capsule becomes the first spacecraft to transmit successfully data from the surface of the planet.
20 September 1970. The Soviet unmanned Luna 16 lands on the Moon's Sea of Fertility. 100 g of lunar soil is successfully returned to Earth on the 24th.

10 Years Ago...
20 August 1975. Viking 1 is launched by Titan 3E Centaur from Cape Canaveral on its 303-day journey to Mars.

5 Years Ago...
11 October 1980. Soviet cosmonauts Popov and Ryumin soft land in Soyuz 37 after spending a record 185 days in space. Ryumin had spent nearly a year in orbit during three space missions.

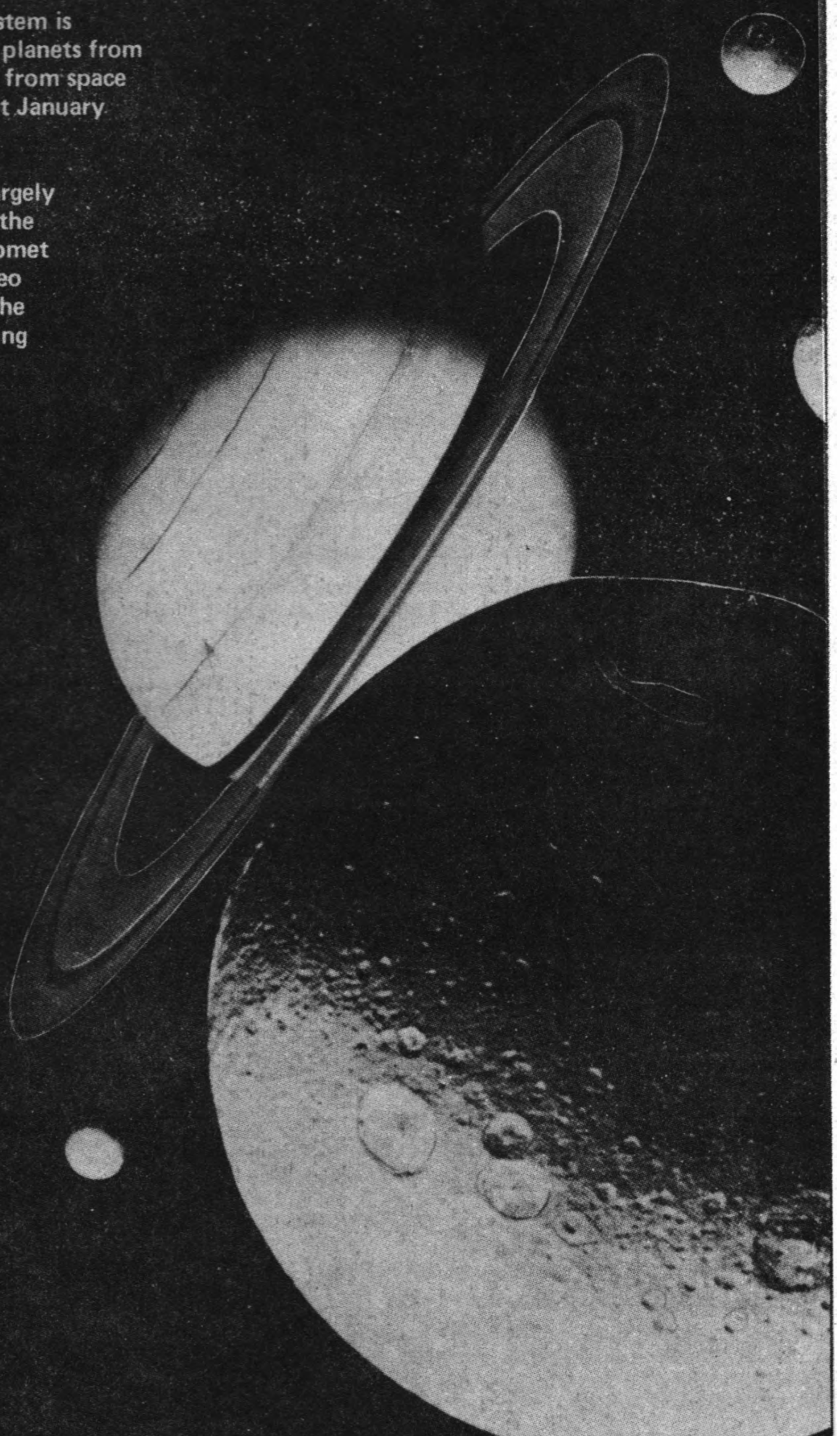
K.T. WILSON

...into the solar system...

Our knowledge of the Solar System is expanding rapidly, with all of the planets from Mercury to Saturn now examined from space probes. Uranus will join them next January with the fly-by of Voyager 2.

Comets and asteroids are still largely unknown bodies. As a prelude to the Giotto investigation of Halley's comet next March and the possible Galileo fly-by of asteroid 29 Amphitrite, the Society is presenting two interesting lectures: 'The Oort Cometary Cloud' on 30 October 1985, followed by 'Our Present Knowledge of the Asteroids' on 20 November 1985 (full details appear on the back cover).

The lectures will prove invaluable as backdrops to these space missions.



spaceflight

Correspondence, manuscripts intended for publication and requests for information on membership may be addressed to the Executive Secretary at the Society's Offices at 27/29 South Lambeth Rd., London SW8 1SZ. Tel: 01-735 3160.

NOTICES OF MEETINGS

Lecture

Theme: **METEORITES: SURVIVORS OF THE EARLY SOLAR SYSTEM**

By Dr. A.L. Graham

Dept. of Mineralogy, British Museum

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on **18 September 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Symposium

Theme: **SPACE STATION APPLICATIONS**

A one-day Symposium on the above theme will be held in the Society's Conference Room on **25 September 1985,** 10.00 a.m. to 5.00 p.m.

The Society has long advocated permanent space stations so this Symposium is an important event in the space calendar. A panel of international speakers will present a series of papers to update present thinking on one of today's major space topics.

Further information and registration forms are available from the Executive Secretary, 27/29 South Lambeth Road, London SW8 1SZ.

40th Annual General Meeting

The 40th Annual General Meeting of the Society will be held in The Grosvenor Hotel, Gallery Lounge, Buckingham Palace Road, London SW1 on Saturday **28 September 1985,** at 3.00 p.m.

Details of the Agenda appear in this issue of *Spaceflight.*

The proceedings will be followed by an Extraordinary General Meeting at which a Resolution to adopt a new Society Constitution will be moved.

Symposium

Theme: **BRITISH LIQUID PROPELLANT ROCKET MOTORS**

A one-day Symposium on the above theme, organised by the Society's History Committee, will be held in the Society's Conference Room on **2 October 1985,** 10 a.m. to 5 p.m.

Registration forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Symposium

Theme: **TOWARDS COLUMBUS AND THE SPACE STATION**

A two-day Symposium on the above theme will be held in Bonn/Bad Godesburg, Stadthalle, W. Germany on **3-4 October 1985,** organised by the DGLR and co-sponsored by the BIS, AAS, AIAA and AIDAA.

Registration forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

36th IAF Congress

The 36th Congress of the International Astronautical Federation will be held in Stockholm, Sweden on **7-12 October 1985.** The theme is:

PEACEFUL SPACE AND GLOBAL PROBLEMS OF MANKIND

Members of the Society wishing to present papers are asked to notify Dr. L.R. Shepherd, Chairman of the BIS International Liaison Committee at Society HQ as soon as possible. Members wishing to present papers to the IAF Student Conference must submit them through the Society.

Lecture

Theme: **THE OORT COMETARY CLOUD: PROBLEMS AND PERSPECTIVES**

By Dr. M.E. Bailey

University of Manchester

The physical structures of comets, observations bearing on their sites of formation and the usual steady-state 'Oort Cloud' theory of cometary origins will be reviewed. Several apparently severe problems for this general picture will then be described, emphasising that the 'Solar System vs Interstellar' debate continues and the validity of the steady-state Solar System model remains unresolved.

To be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on **30 October 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

Lecture

Theme: **OUR PRESENT KNOWLEDGE OF THE ASTEROIDS**

By Prof. A.J. Meadows

University of Leicester

To be held in the Society's Conference Room, 27/29 South Lambeth Rd., London SW8 1SZ on **20 November 1985,** 7.00-9.00 p.m.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Library will be open to members from 5.30 to 7 p.m. on the following dates:

18 Sept, 2 Oct, 30 Oct and 20 Nov.

Membership cards *must* be carried and be available for inspection before admittance.

While every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

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